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SAND COULEE/BELT COAL FIELD

RECLAMATION — ENGINEERING STUDY

CASCADE COUNTY, MONTANA

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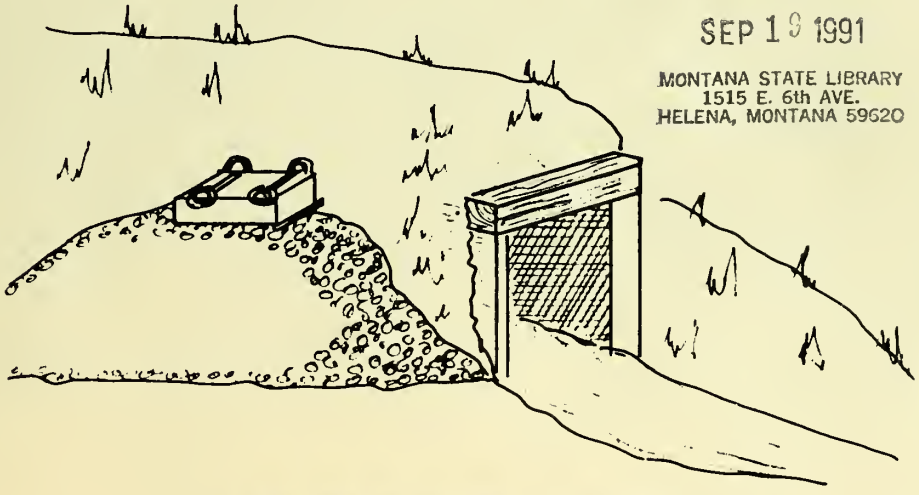

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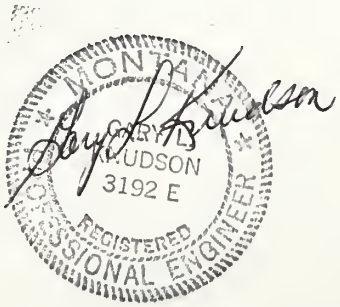

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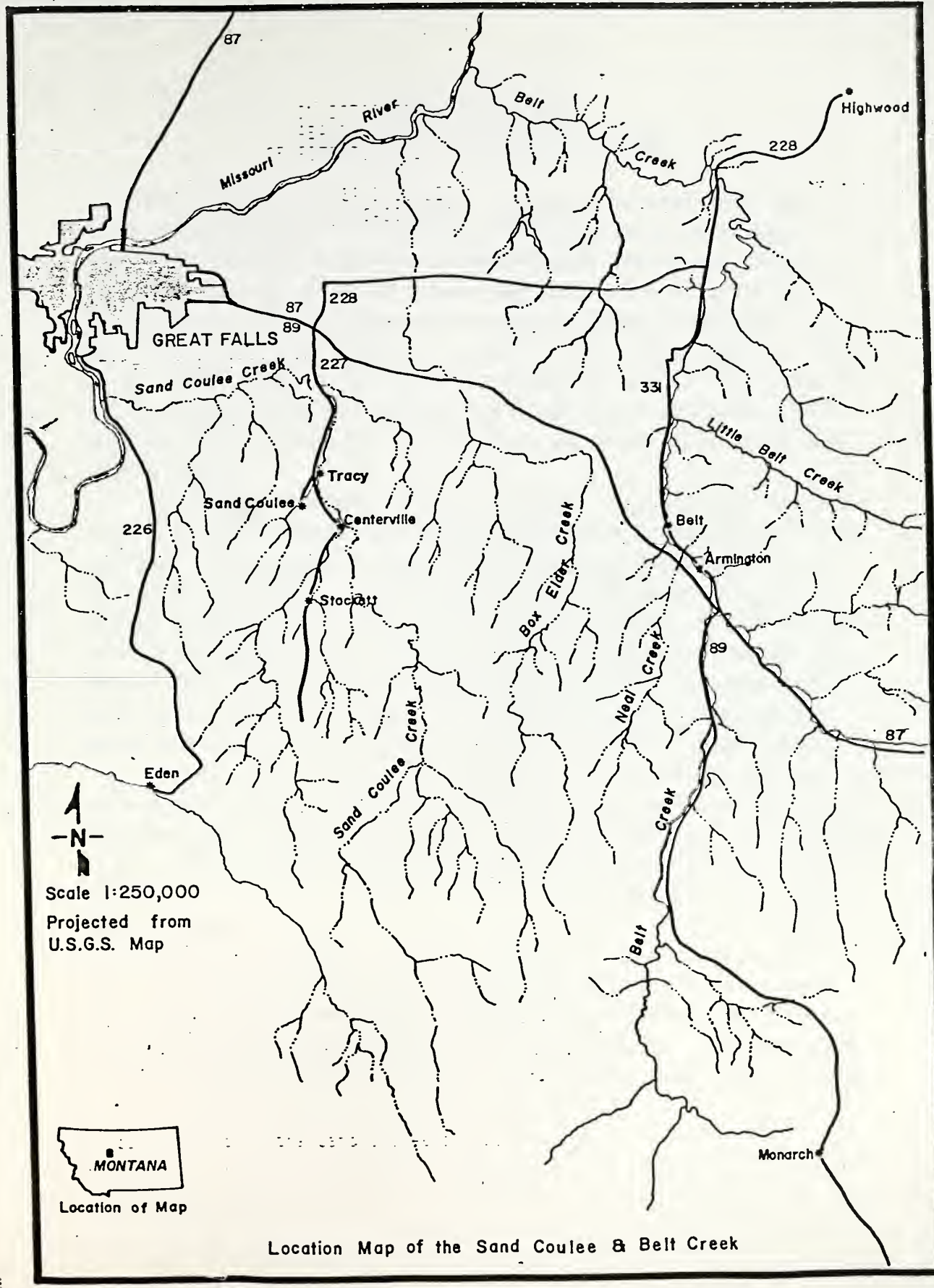

Location Map of the Sand Coulee & Belt Creek

SAND COULEE/BELT

RECLAMATION - ENGINEERING STUDY

Five abandoned underground coal mines located near the towns of Centerville and Stockett, Montana and a sixth site near Belt, Montana represent a significant health and safety threat to the residents of these communities as well as the land owners. All of these sites contain large volumes of coal mine wastes, slack, tailings, and other associated debris. Two of the sites have a continuous discharge of acidic mine effluent which is destroying all vegetation along their drainage paths and which contribute some of the flow and contamination of Sand Coulee Creek.

Runoff from several of these sites is washing away the mine wastes which are eventually redeposited down gradient and either increase the sediment loading of Sand Coulee Creek and/or are gradually invading and destroying cropland located along the valley bottoms below these sites. Runoff and precipitation percolating through the coal/slack and mine waste piles leach the metals from the coal wastes increasing the iron, sulfate, and zinc levels which contaminate the naturally occurring surface water and ground water and also destroy soils and vegetation.

Several of the sites have open portals which extend into former underground workings, and represent a major nuisance and safety hazard. Many of the old entry ways and adits are substantially failed and/or collapsed, posing a serious threat to all persons, livestock, or other animals venturing into the areas.

INTRODUCTION

An investigation of the five abandoned mine sites in the Centerville/Stockett area and the abandoned mine site at Belt was conducted for the Montana Department of State Lands, Abandoned Mine Reclamation Bureau. The investigation was completed in accordance with the tasks set forth in the Sand Coulee - Belt

Coal Field, Cascade, Montana Reclamation Engineering Study Proposal. Objectives and goals for this investigation were based upon the Rules and Regulations established for Montana's Strip and Underground Mine Reclamation Program. This program as stated for abandoned mine reclamation efforts states that reclamation efforts in identified abandoned mine areas should result in certain benefits as follows:

(a) protection of human life, health, or safety;

(b) protection of the environment, including air and water quality, abatement of erosion and sedimentation, fish, wildlife and plant habitat, visual beauty, historic or cultural resources, and recreation resources;

(c) protection of public or private property;

(d) abatement of adverse social and economic impacts of past coal mining on persons or property including employment, income and land values or uses, or assistance to persons disabled, displaced, or dislocated by past mining practices;

(e) improvement of environmental conditions which may be considered to generally enhance the quality of human life;

(f) improvement of the use of natural resources, including post-reclamation land uses which:

(1) increase the productive capability of the land to be reclaimed;

(2) enhance the use of surrounding lands consistent with existing land use plans;

(3) provide for construction or enhancement of public facilities;

(4) provide for residential, commercial, or industrial developments consistent with the needs and plans of the community in which the site is located;

(g) demonstrate to the public and industry methods and technologies which can be used to reclaim areas disturbed by mining.

Additional considerations outlined in Montana regulations include economic costs and efficiencies of reclamation.

The Reclamation - Engineering Study for the Sand Coulee/Belt Project is under the direction of Delta Engineering, Great Falls, Montana. Sub-contractors for this project include David Stiller and Associates, Helena, Montana, and William M. Schafer, Ph.D. and Stephen J. Harvey, both of Bozeman, Montana.

Delta Engineering completed all of the technical requirements and the engineering investigation and analysis. David Stiller and Associates compiled the hydrology and geological requirements; Dr. William Schafer directed all work related to the soils investigation, testing, and analysis; and Mr. Stephen Harvey directed all revegetation and reclamation studies and recommendations.

Reconnaissance studies were made to examine impacts and hazards associated with each site. These studies included an examination and evaluation of the soils, vegetation, hydrology, geology, geotechnical, and the engineering concerns at each site. Major emphasis was placed upon the quantity and nature of the mine wastes and tailings dumps, the condition and potential failure of the open mine workings, the acid mine discharge and result-

ing erosional and polluting effects on the soils and adjacent vegetation.

PURPOSE AND SCOPE

A detailed investigation of the abandoned mines in Belt and Sand Coulee, Montana was completed in 1982 in a joint study by Western Technology and Engineering, Inc. and Hydrometrics, both of Helena, Montana. This study was a comprehensive investigation of the environmental problems in these areas including socio-economic impacts, vegetation, soils, air quality and hydrology. The environmental impacts and hazards of each abandoned mine site in these two areas were investigated in detail for these parameters. Results of this study were integrated into a master plan describing recommended reclamation projects, pollution abatement, disturbed land restoration, monitoring, and recommended future work.

As a follow up to the initial Reclamation Study, abandoned mine sites presenting the greatest threat to health and safety or having the most significant impact on the environment were prioritized for subsequent reclamation. Priority sites would then be further investigated to develop a cost effective and technically feasible reclamation program to eliminate control, or mitigate the existing and/or future environmental problems created by these abandoned mines.

This particular projectinvolves the reclamation and engineering evaluation for six sites. These sites are:

1. Centerville "C" - Centerville, Montana

2. Stockett-West Ridge - Stockett, Montana

3. (a) Upper Cottonwood A - Stockett, Montana

   (b) Upper Cottonwood B - Stockett, Montana

   (c) Upper Cottonwood C - Stockett, Montana

4. Anaconda Mine - Belt, Montana

See Location map for identified sites.

Work specifically completed for this Reclamation/Engineering Study include:

1) Literature search and review of previous studies and reports regarding soils, vegetation, hydrology, geology, and reclamation recommendations for each site.

2) Field visit and site investigation to evaluate environmental concerns and problems, collect additional field information and soils and water samples where required.

3) Hydrology - Surface water and ground water investigation and determination of mine discharge quality and quantity.

4) Geologic investigation of affected area with emphasis on technical consideration for engineering evaluation.

5) Soils investigation to determine extent and quantities of mine wastes and tailings, and treatment and amendment requirements for reclamation and/or disposal.

6) Vegetation inventory and analysis to establish revegetation plan and seed mixture requirements for each site.

7) Preliminary Engineering evaluation and analysis to determine site specific technical requirements and establish various engineering alternatives to reduce or eliminate the safety and environmental problems.

STUDY AREA

History

The Blackfoot Indians roamed the study area when Lewis and Clark passed through in 1804 and 1805. The region was settled in the late 1800's due to a boom in mining, livestock grazing, and farming. Cascade County is currently among the largest producers of agricultural products in the state.

The earliest recorded coal mining was in 1876 near Belt. In the heyday of mining before 1940, the largest coal mining operations were centered at Belt, Stockett, and Sand Coulee. Most of the estimated 36 million tons of bituminous coal produced from underground mines was used to power railroad locomotives.

Geologic Setting

The Sand Coulee - Belt study area is located on the northwest flank of the Little Belt Mountains 12 to 18 miles east of Great Falls, Montana. The area lies just south of the extent of major continental glaciation (Keewatin ice sheet) demarcated by the Shonkin sag north of the nearby Highwood Mountains.

The surficial geology in the study area consists of a series of gently sloping benches with shallow to deep soils over sandstone bedrock. Benches are dissected in places by drainages such as Belt, Sand Coulee, Sand Coulee Creek, and Cottonwood Creek. Local relief along many drainages ranges from 150 to 300 feet.

Several coal seams are found in the area at the top of the Morrison Formation which is Jurassic in age. The Morrison in the study area consists of thinly-bedded, weakly-consolidated shales and mudstones. The Kootenai Formation immediately overlies the Morrison, and provides the structural erosional control of the prominent bench-like uplands typical of the area. The Kootenai is a massive jointed sandstone with dramatic cross-bedding.

Soils

A variety of soils are found in the study area. Soils can be classified into three geomorphic divisions including nearly level bench-like uplands, soils on steep dissected areas adjacent to the coulees formed by perennial streams in the area, and soils of the floodplain river bottoms (Clark and others 1982). An understanding of the areas soil resources is essential to adequate reclamation, as these materials must be used extensively for cover material for the disturbed areas.

Soils of the upland benches consist of deep to shallow soils derived from sandstone alluvium. They are mostly used for dryland small grain and range forage production. Soils are in the Ipano, Bitton, and Castner series. Ipano soils are classified as fine-loamy, mixed Typic Calciborolls. They contain 18 to 35 percent clay, have darkened surface horizons more than 10 inches thick, are more than 40 inches deep, have strong accumulations of lime, and occur on slopes of less than 4 percent. Castner soils occur on the edges of the uplands near dissected areas or along ridges. They are classified as loamy-skeletal, mixed Lithic Haploborolls.

They are less than 20 inches to indurated sandstone bedrock, have thick darkened surface horizons, and contain more than 35 percent sandstone rock fragments.

Soils along the dissected margins of benches belong to the Castner and Bitton soil series. Castner soils were described above. Bitton soils are classified as loamy-skeletal, mixed Entic Haploborolls. These soils are common along the alluvial fan footslopes blanketing the base of escarpments bordering area streams, while Castner soils are common upslope in steep areas just below the sandstone caprock. Bitton-like soils will often represent the closest available cover soil material for project reclamation. Bitton soils are more than 40 inches deep, have thick darkened organic-matter rich topsoil, a shallow "C" horizon with moderate accumulation of lime, and more than 35 percent sandstone rock fragments.

Soils in recent floodplain river bottoms occur as a narrow ribbon following perennial streams in the study area. The Straw and Glendive series are common. Straw soils are classified as fine-loamy, mixed Cumulic Haploborolls. They are more than 40 inches deep, are dark-colored throughout, and have 18 to 35 percent clay. They occur at the base of slopes where organically-enriched sediment accumulates. Glendive soils are more common. They are coarse-loamy, mixed (calcareous), frigid Ustic Torrifluvents. Glendive soils contain less than 18 percent clay, are more than 40 inches deep, and are light colored throughout.

Mining Impacts

Mining in the Sand Coulee - Belt area has left a legacy of

environmental consequences that has had significant economic impacts throughout the region. Numerous mine portals dot the hillsides bordering Sand Coulee Creek, Cottonwood, and Belt Creeks. Associated with most portals is a waste dump of low grade waste coal and carbonaceous shale. Some waste dumps have burned in the past leading to formation of a fused slag deposit.

The coal seam mined from the top of the Morrison Formation outcrops along the length of most drainages. Since the coal cropline follows the hillslope, any water collecting in the mine workings readily flows to the soil surface. Much of the water seeping from the mines in this manner has developed a low pH from pyrite oxidation. Characteristic acid seeps are a common result through much of the mining district. Many portals that remain open today have water discharging from them, which is also low in pH. This acid mine drainage (AMD) from the portals and seeps has impacted most of the surface water in the Belt and Sand Coulee watershed, turning the stream channel a telltale orange color from "yellow boy" hydrous iron oxide precipitation.

In addition to the soil and water contamination noted above, mining activity has almost certainly impacted local ground water quality. The mine workings themselves represent a safety threat to persons or livestock that might enter the abandoned mines.

Site Location

The study area is located from 12-18 miles east of Great Falls, Montana in Cascade County. Towns nearest the sites include Belt, Centerville, and Stockett.

Sites are named in accordance with terminology used in the

Abandoned Mine Lands National Inventory conducted by the Montana Department of State Lands (Appendix A). The Centerville "C" site is a large waste dump and portal with AMD located just north of the community of Centerville (Figure 1). The Stockett site is a large area adjacent to the west side of Stockett. A portal and numerous scattered waste piles as well as severe offsite erosion are evident at this site (Figure 2). The Belt site is a mine portal and waste dump just south of the community of Belt (Figure 3). The Upper Cottonwood Sites (A, B, and C) are mines acid seeps, portals and disturbed areas on the east side of Cottonwood Creek upstream from Stockett (Figure 2).

LITERATURE REVIEW

Acid Mine Drainage

The subject of acid mine drainage (AMD) formation, abatement, and treatment has been discussed extensively in the literature (Caruccio 1968, Caruccio and Geidel 1978, Geidel 1979). In this review, only the salient points concerning iron disulfide oxidation will be summarized.

Generation of AMD has long been associated with pyrite oxidation. Microorganisms greatly speed the reaction rate in most environments. For every mole of pyrite oxidized, four or more moles of acidity are produced depending on the reaction pathway. The net effect of pyrite oxidation depends not only on the quantity of pyrite, but also its crystal form, particle size, trace metal constituents, and on the quantity of acid-neutralizing carbonates in the system. The acid-base balance is a measure of the net acid-producing or neutralizing capacity of sediment.

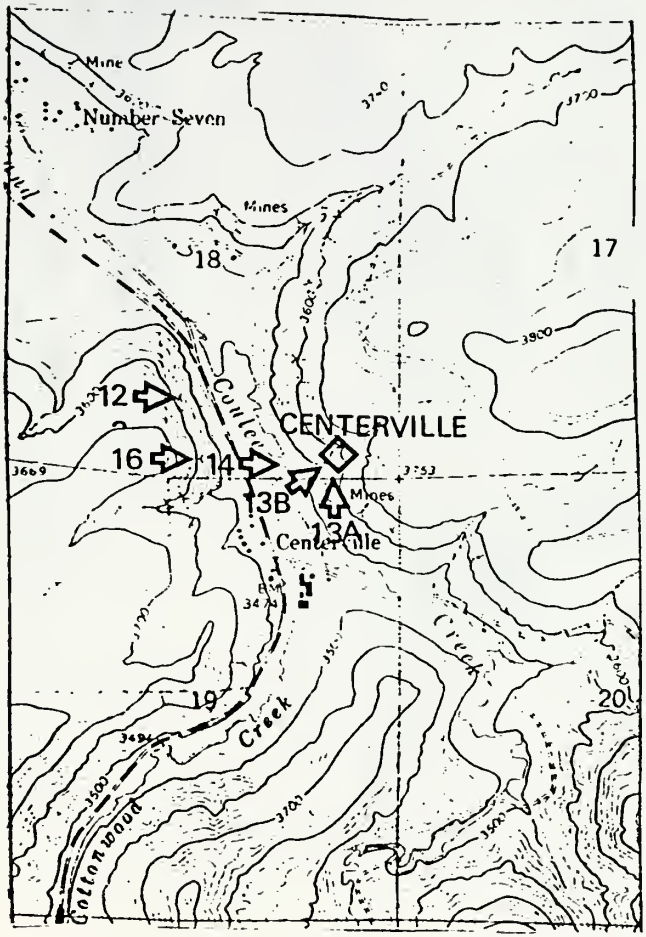

Figure 1. Location of the Centerville "C" site and soil sample locations (Southeast Great Falls, MT 7.5 minute quad, U.S.G.S.).

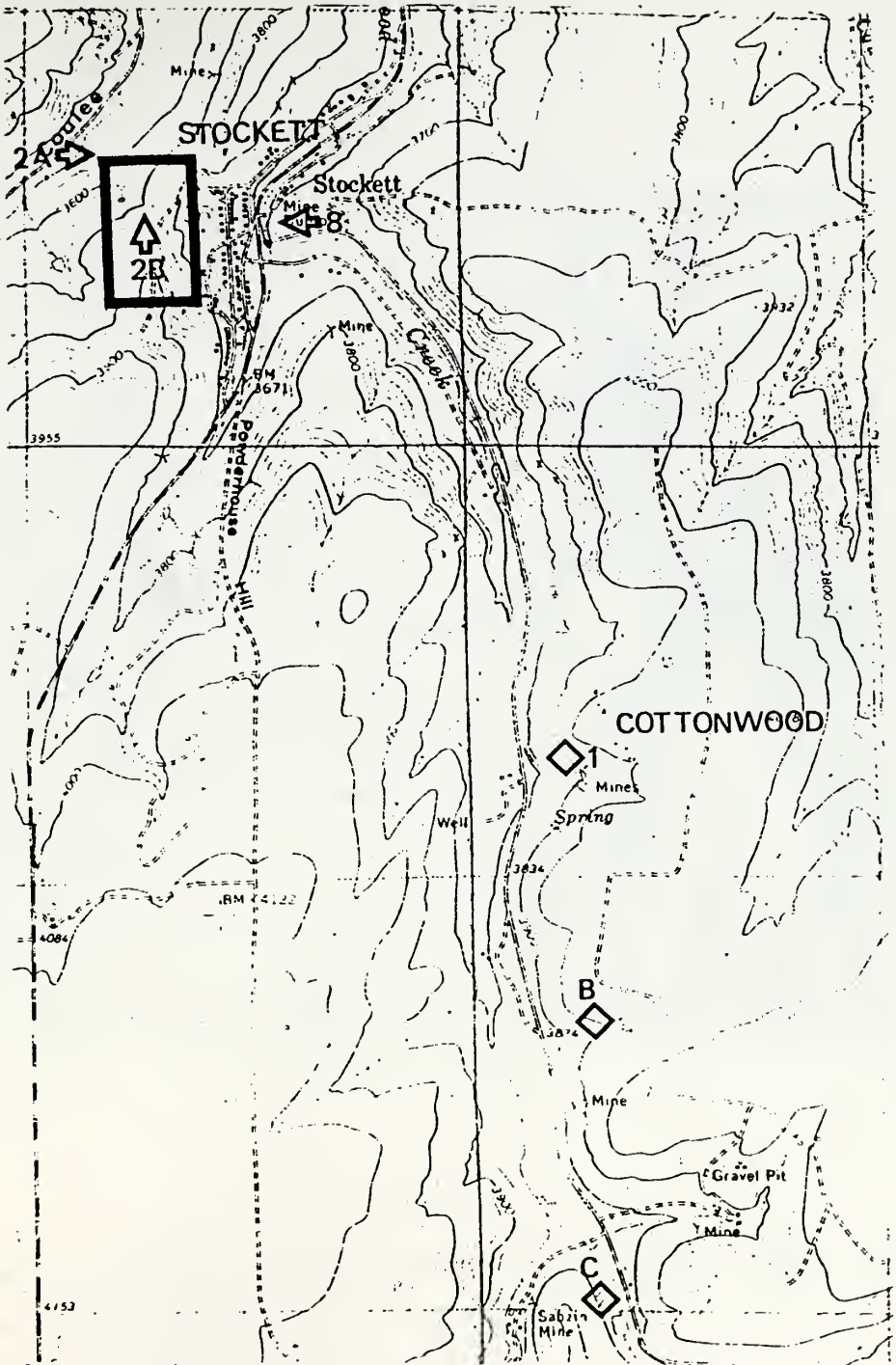

Figure 2. Location of the Stockett and Cottonwood reclamation sites, and soil sample locations (from Stockett, MT 7.5 minute quad U.S.G.S.).

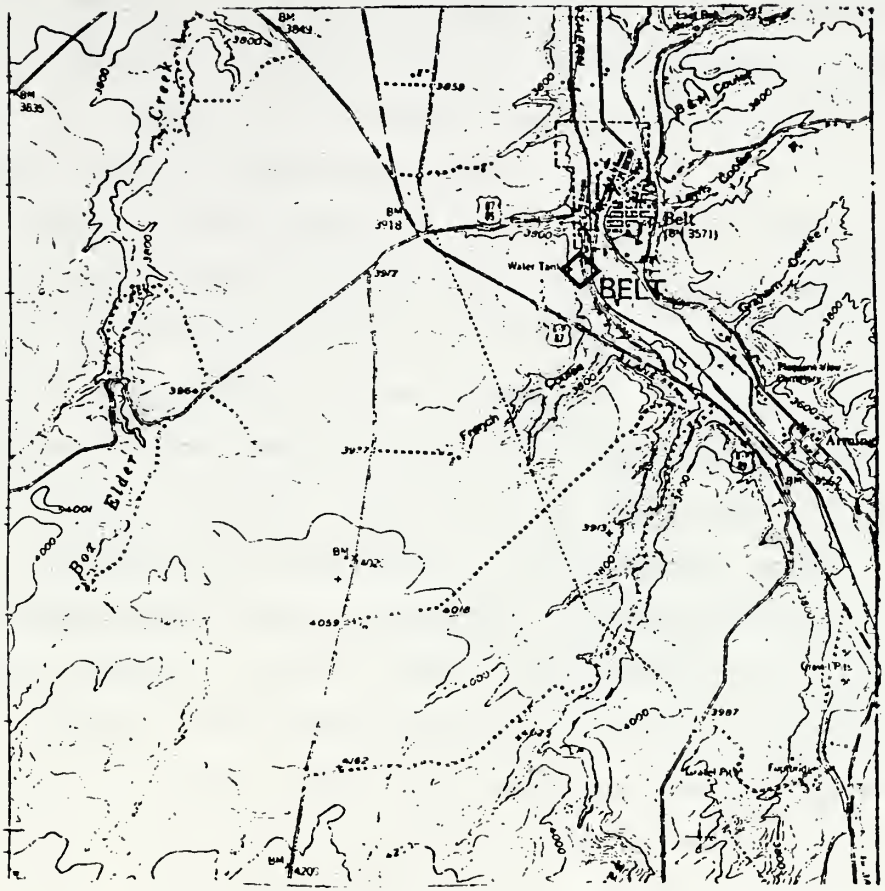

Figure 3. Location of the Belt reclamation site (Belt, MT 15 minute quad, U.S.G.S).

For each one percent total sulfur measured, a lime requirement of over 50 tons per acre results (to neutralize the acidity).

Pyrite oxidation is also affected by a number of environmental conditions. Oxygen is required for pyrite oxidation to occur. Oxygen diffusion in water is several orders of magnitude slower than in air. As a result, pyrite oxidation occurs most rapidly in moist aerobic sediments.

Another obvious requisite for development of AMD is a source of water percolating through pyritic materials. Reduction in ground water recharge or diversion of surface waters from pyritic wastes is a feasible abatement technique. Reduction of shallow ground water flow through changes in dryland cropping practices is a subject of special interest in the study area (see section III - Recharge area management). An alternative method for controlling water where AMD occurs is through pneumatic sealing of mine openings. Though costly, the technique is often successful. However, the tendency for seeps to develop through the coal cropline in the Sand Coulee area make it impossible to secure a seal which will contain a significant hydrostatic head.

Geidel (1979) and others have shown that in sediments with a mixture of pyrite and neutralizing materials, that the frequency of flushing by water influences the pH of AMD. In sediments with ample carbonate and rapid water flux, the carbonate which equilibrates quickly with water readily neutralizes acid produced. Pyrite oxidation is kinetically slower than carbonate equilibria but solubility is far higher. As a result, sediments with infrequent flushing will develop water with a low pH despite an

abundance of carbonates. This may explain the occurence of acid seeps in soil containing lime in the subsoil.

Reclamation Techniques

Reclamation strategies for abandoned mine areas are in a sense as numerous as the sites that have been reclaimed. However, a generalized summary of approaches to reclamation of these sites is useful.

The primary cost of any land reclamation project is for earth-moving and regrading activities. Therefore, a classification of reclamation approaches might best be based on the kind of regrading performed.

The simplest, most economical approach would involve little earth moving. Soils and wastes would be amended with lime and fertilized to correct for acid and nutrient problems, topsoiled if necessary, and a cover crop of grass would be planted. This approach, though simplistic deserves consideration for less impacted areas like acid seeps. The vegetative cover reduces erosion and improves aesthetics while using water which may infiltrate the spoils, helping reduce further acid generation.

Another approach would be to contour existing waste dumps in order to reduce either slope lengths or gradient thus reducing erosion. Diversion of surface waters away from pyritic materials would also be effected. This approach could be combined with soil amendment and direct seeding where conditions permit. More often, however, some kind of cover-soil material would need to be placed over the disturbed site as a plant growth medium. Cover-soil depths would be dictated by local climate, spoil toxicity, vegetation type, and ultimate land use goals.

A more costly approach, but one of necessity where extreme contamination is occurring, would involve removal of waste materials from a site. The waste could be buried in a location more isolated from surface and ground water sources. Recontouring and application of soil amendments to the original land surface would complete preparation of the site for planting. Waste materials could be spread and contoured on a level site where little erosion or recharge from ground water would occur. Excavation and burial would be another option.

A special approach to removal of mine waste is represented by various techniques used for mine backfilling. A pneumatic or air-injection technique has proven effective and economical in many situations. Using this approach, the dual purpose of waste removal and mine backfilling can be served. Backfilling can reduce mine subsidence and reduce AMD through reduction in oxygen flux to the pyritic materials. However, backfilling of wet adits may be hazardous due to hydraulic head pressures on the backfill material.

Lime Grades and Standards

Application of lime or other acid neutralizing material will almost certainly be a part of any AMD abatement and reclamation project. Lime is used widely in the midwestern and eastern U.S. for correction of acid pH in agricultural soils. The neutralizing capacity of various grades and standards of lime are well documented in the literature. Where the use of lime is necessary, specifications should always be made of the type and fineness of product to use.

Two factors affect limestone effectiveness, its calcium carbonate content and its fineness. Liming materials are evaluated

on the basis of their "calcium carbonate equivalent", the neutralizing power of pure powdered $CaCO_3$, rated at 100.

Finely ground liming materials react quickly with the soil to reduce acidity, while large particles react too slowly to be effective. Use the table below as a guide to the relative effectiveness of various particle sizes. Typical limestone materials have a lime equivalent of about 1,000 pounds per ton. All lime recommendations must be adjusted for the lime equivalent of the material used.

Table 1. Relative neutralizing capacity of different fineness grades of lime.

Mesh size (#/inch)	Effectiveness
larger than 4	0%
4 to 8	10%
8 to 60	40%
smaller than 60	100%

Limestone is immobile in soil, so it must be incorporated to the depth which requires neutralization. Incorporation and mixing of lime to deeper than 6 inches is difficult with most equipment.

The quantity of lime required to raise a pH to around 6.5 depends on actual soil pH and on the buffering capacity of the soil. Clay and organic matter content affect soil buffering. To raise the soil pH of a typical sandy loam soil from pH 3.0 to 6.5 may require 2.5 tons lime per acre. To raise the pH an equivalent amount for a clay loam soil would require 7 to 10 tons per acre.

RECLAMATION APPROACH

Regrading/Channel Design/Drainage

The primary costs in a reclamation project are associated with earth-moving activities. Reclamation strategies were chosen to provide a least-cost alternative to satisfactorily reclaim each site. Two basic regarding approaches are recommended. For most sites involving waste materials, slope reduction of the waste piles, and cover with adequate soil material is advised. At the Centerville "C" site, removal of the waste to the base of the slope, and construction of a fill would minimize erosion. Waste material at the Belt site could be used to fill the collapsed portal area of the site.

During slope reduction of waste piles, the basal area of the piles will be increased 1 to 1.5 times. Suitable cover-soil should be removed from the areas to be covered, and replaced on top of the fill.

Water draining from several portals in the study must be prevented from eroding recontoured areas. Some sort of stable channels will need to be devised to convey this water off the site. A gravity-fed pipe system may also be suitable for removal of water, but may eventually clog with hydrous iron oxide precipitates.

Many seep areas will be a continuing problem unless the source of water feeding them is reduced or eliminated. In many cases, a sealed portal has caused water to back up into old mine workings. The hydrostatic head developed causes the acid water

to seep through the permeable coal to the cropline at the soil surface. Opening these portals may relieve the accumulated head.

Artificial drainage systems may also be needed to collect subsurface water before it surfaces. Horizontal drilling and placement of drainage pipe, or construction of shallow (3 to 4 feet deep) curtain drains, or a system of main and lateral drains may sufficiently reduce subsurface flows of acid water to insure maintenance of the reclaimed acid seeps.

Erosion Control

On reclaimed slopes with greater than 20 percent slopes, or slope lengths greater than 200 feet, it may be necessary to install engineering structures to reduce erosion. Backsloped contour terraces could be used to collect runoff which could be conveyed down a protected rock-lined drop or spillway.

On other erosion-prone slopes, mulching may protect soil from erosive rains until a vegetative stand becomes established. The use of a large crawler tractor "tracking" up and down the slope over broadcast seed and mulch has been demonstrated to be an effective method for erosion control. A variety of mulching materials could be effective. Many sites will prohibit crimping of crop residues due to the steep slopes and high rock fragment content. Hydromulch may be desirable on these sites as it allows remote application of mulch, seed, and starter fertilizer.

Cover Soil

With the exception of acid seeps, all reclaimed sites will require some sort of cover-soil material to insure adequate establishment of vegetation. Soil material should be borrowed at the closest possible location adjacent to the site. In many

cases, locally available soils do not have ideal characteristics for plant growth (Schafer, 1979). Primary limiting factors of most soil materials would be high rock fragment content, and occasionally heavy soil textures.

Care should be taken in removing soil from offsite that at least 12 inches of soil material remains in place for borrow site revegetation-18 inches if rocky. A minimum of 16 inches of cover-soil should be placed over regraded waste materials. This minimum should be increased proportionately if cover-soil contains abundant rock fragments.

Soil Amendments

Agricultural lime will need to be applied to most sites to correct acid pH problems. Lime will be applied in two situations. The first is where an acid seep has developed. These soils have pH ranging from 2 to 4.5 throughout the root zone, but unlike waste materials, they have no residual sulfidic materials to cause further acid generation (Appendix B). Once the flow of subsurface water is eliminated, the acidity can be neutralized with lime applications of 5 to 10 tons per acre.

Waste materials covered with cover-soil materials should also be lime-treated to increase the effective root zone depth and to neutralize upward movement of acidic material into the cover-soil. Lime rates for waste materials is higher than for soils because of the potential for sulfides in the waste to contribute to future acid production. Lime rates for waste materials are set at 40 tons per acre or 2,000 pounds per 1,000

square feet. This assumes that the wastes have about 1 percent potentially oxidizable sulfur.

Soils that have had AMD running across them at Stockett and Cottonwood "B" sites will need only 2.5 to 5 tons of lime per acre (150 to 200 pounds per 1,000 square feet) to reclaim them. Many soils affected by acid seep have a high electrical conductivity (4 to 6 mmhos per cm). Salt tolerant species should be utilized in these areas (Appendix C).

Fertilization

Many of the waste materials had significant amounts of both nitrate and extractable ammonium nitrogen. Other studies have found coal waste to be a significant source of plant-available nitrogen (Reeder and Berg 1977). Cover-soil materials are expected to be low in nitrogen and phosphorus, but adequately supplied with potassium which is typical of most soils in Cascade County (unpublished data).

Excessive applications of nitrogen before planting can stimulate weed growth especially where native species are used in the seed mixture. However, by not providing sufficient nitrogen, a stand may lack the vigor required to survive the first growing season. Nitrogen is often the nutrient in least supply in reclaimed soil-plant systems (Schafer and others 1977). A split nitrogen application is recommended to circumvent these problems. Twenty pounds of fertilizer N should be applied preplant as mono-ammonium phosphate (11-55-0), with another 20 to 30 pounds added later in the first growing season of ammonium nitrate (34-0-0).

The fertilizer program outlined above will provide 100 pounds of P_2O_5 with the pre-plant nitrogen application which should be adequate for native grasses and shrubs.

Tillage

The purposes of tillage are many: to incorporate residue or fertilizer into the root zone, to prepare a seedbed for planting, or to control weed growth. Tillage will be addressed in this section as a means of incorporating lime and fertilizer into reclaimed soils.

If possible, traditional agricultural implements should be used for liming, fertilizing, and seeding operations. Where slopes, access, or expense is limiting, earth-moving equipment can be used to provide a minimal amount of tillage after lime and fertilizer has been surface applied.

After the site has been regraded and cover has been spread and allowed to settle, then lime and fertilizer can be spread across the disturbed areas as needed. After application, the soil surface should be disced in two directions to incorporate the materials into the root zone. Alternatively, caterpillar shanks (3 foot spacing) should be run at 1 foot in depth twice in two directions (4 times over). The surface can then be prepared for a drill planter with a light chisel plow or harrow operation. If the seedbed is rough and cannot be tilled properly then a fall broadcast seeding, late winter (frost mulch) seeding, or spring hydromulch seeding is recommended.

Recharge Area Management

In much of the Sand Coulee area, the primary source of water

contributing to AMD is deep percolation below upland bench cropland. The same process contributes to the formation of saline seep throughout the Triangle region of Montana. A comprehensive review of saline seep is not necessary in this report. Publications outlining the causes of saline seep are appended (Appendix C).

A large scale cooperative program to identify significant recharge areas for AMD, and use of alfalfa plantings, deep-rooted perennial grasses, or continuous (rather than alternate crop-fallow) grain cropping could be used to reduce or eliminate the flow of shallow ground water to the mines. Economic incentives may have to be provided to encourage area producers to change their crop-fallow sequence. Once most farmers try a flexible-cropping or continuous crop system, they seldom return to crop-fallow.

Site Description

Centerville "C"

The Centerville "C" site is located in the SE 1/4 Section 18, T 19 N., R. 5 E. Cascade County, Montana at the northeastern edge of the Town of Centerville, Montana. The old portals and the associated mine wastes are situated along the edge of a fairly steep hillside in a natural ephemeral drainage which is tributary to Sand Coulee Creek Elevation of the former adits is about 3,600 which is 140 feet above the creek bottom. The workings and wastes lie almost directly across the highway from the Centerville Senior Citizens Center. The site is on land owned by O. E. (Gene) Johnson of Tracy, Montana.

The site consists of a large pile of mine waste and coal slack which were dumped along the face of the hillside separated in part by two small Coulees. The Coulee along the north side of the waste site is natural and drains about 40 acres of bench area above the site. The Coulee along the south side of the waste pile was created by the placement of the dump and the excavation into the hillside for the former adit. This Coulee currently contains the discharge emanating from the mine.

The mine wastes cover an area of slightly over 1/3 acre in size and contain an estimated 6,000 to 7,000 cubic yards of material. Most of the waste material is clinker which has resulted from one or more fires burning through the previous coal wastes.

There are apparently two former adits associated with this site. The main adit lies at the upper most southeast edge of the waste pile along the base of a massive sandstone outcrop of the Kootenai formation. This adit is completely filled in with material and access into the mine is not possible.

The other adit appears to be located along the face of the hillside on the north side of the original drainage. No portal or entry way is apparent, although a pile of slack and mine wastes along this side of the hill suggests a possible former adit.

The main adit is filled with material and the portal sealed off. The entry way into the adit has been filled with somewhat pervious materials and an acidic discharge issues from the fill materials near the base. This discharge flows at a rate of 6 gallons per minute (gpm) and is typical of AMD; i.e. pH about 3.00, high sulfide, and iron. The discharge flows down the

Coulee and merges with seepage flowing from the face of the waste pile. The discharge eventually flows into Sand Coulee Creek.

The embankment/slope along the south side of the Coulee below the main adit area is completely saturated along much of the face and a progressive sloughing is gradually eroding away the embankment. This saturation is apparently the result of seepage from the mine which is in turn washing away the topsoil and killing the vegetation.

Stockett - West Ridge

The Stockett West Ridge site is located along the western edge of the town of Stockett, Montana, primarily in the northern portion of the SW 1/4, Section 36, T19 N, R 4 E. The area of disturbance lies along the crest and on the western and eastern flanks of the "West Ridge". This ridge is between Number Five Coulee on the west and the Stockett - Centerville highway on the east. Owner of the land, containing the old workings and most of the impacts, is Ralph Singles. Some disturbance due to runoff and erosion has occurred in a cultivated field west of the site which is owned by Ernest Chartier.

There is an estimated 3 to 5 acres of mine wastes, clinker, debris, and trash associated with this site. Much of the waste and disturbance are the direct result of previous coal mining activities; however, the site was formerly used as a land fill dump, and consequently some of the existing disturbed area and the scattered debris and trash are landfill related.

Runnoff from snowmelt and precipitation have channelized the mine wastes in several areas, primarily along the west slope

of the ridge. The washed out waste material from these channels including other materials washed down the face of the slope have accumulated along the base of the hillside. This base forms the edge of a large flood plain of the No.5 Coulee which is also a productive farming area. A large cultivated field located between the No. 5 Coulee road and the west side of the ridge has been incised by runoff from the disturbed area leaving a 3 to 4 foot deep channel across its width.

Two seeps emerge from the waste piles on the east side of the ridge and flow down hill towards the town of Stockett. These seeps collect in a ditch which eventually discharges into Cottonwood Creek.

No open portals or adits are present on the site. There are three covered or filled-in mine entries which will have to be further backfilled and regraded.

Upper Cottonwood "A"

The Upper Cottonwood "A" site is located up Cottonwood Coulee approximately 2½ miles southeast of Stockett, Montana. The location of the above land mine is in the extreme south end of the SE 1/4, Section 7, T. 18 N., R5E. The land owners are Clem and Milly Mayernik of Stockett, Montana.

The abandoned mines disturbance contains less than ½ acre of mine waste piles and two former adits. These adits are filled in and only the excavated area for the entry into the ruins is still evident. The mine spoils piles are located less than 100 yards from a water reservoir discharging good quality water into a tributary to Cottonwood Creek. A former channel

of the tributary stream was once located along the base of the hillside and directly below the waste piles and former workings. The channel has since been rerouted several hundred feet away; however, the former channel still provides a water course for some surface water during periods of high rain fall or snowmelt. Some of the water remains ponded in the abandoned channel. Run-off and percolation of water from the slack piles also accumulates in the channel and elevate the iron and sulfide content. The water eventually discharges into the tributary stream.

Upper Cottonwood "B"

The Upper Cottonwood B site is located along Cottonwood Coulee about 2¼ miles southeast of Stockett, Montana. The site covers less than 2 acres in the northern part of the SW ¼ Section 7 T. 18 N., R. 5 E. The land is owned by Mr. Matthew Takala of the Stockett area.

The site contains two small adits extending about fifteen to twenty feet each into the flank of the hillside. The excavations were made through several feet of sandstone which is highly fractured and has partially collapsed sealing off the underground workings beyond the initial portal opening. Three large piles of mine wastes are located downslope about 200 feet north of the old portals. These piles contain an estimated 1,000 to 1,500 cubic yards each. These piles contain considerable carbonaceous shale and coal wastes and are believed to present a pottential fire hazard. There is considerable other mine waste primarily slack and some cinder material scattered about the site, much of it along a former haul road to the site. Most of this material was apparently used as fill for the road.

Upper Cottonwood "C"

The Upper Cottonwood C site is located along the hillside above the county road on the east side of Cottonwood Creek. The site is about 2 miles southeast of Stockett, Montana. The total disturbed area contains between 4 and 5 acres of land located in the SW ¼ Section 6, T 5.E., R. 18 N. The land owner is Bill Singles of Stockett, Montana.

There are two separate former adits associated with this site. The lower adit measures approximately 5' high by 12' wide and is open for approximately 100 feet into the hillside. Much of the adit has collapsed and contains numerous boulders and rock slabs which have fallen from the roof and have partially filled the adit area. Although the former mine workings were probably extensive, access is limited due to the collapse of the roof and the accumulation of fallen rock. There is an adjacent excavation into the coal seam about fifty feet south of the open adit. This excavation is only about 6 feet high by 10 feet wide and extends about 10 feet into the coal. Both of these lower openings are located along the face of a narrow scarp above a natural coulee. This coulee contains much of the waste material of and discarded coal from the mine.

The second adit is located about 200 yards above the first adit. The second adit and former portal are collapsed and partially covered over with rock and earth material. The former entry into the mine which was excavated into the hillside, has been partially bridged from the roof collapse and has created a small dam in the collapsed area. A continuous discharge

flows along a constructed ditch down the hillside for about one-half mile where it dumps into Cottonwood Creek.

The mine wastes from the lower mine workings were dumped in a natural coulee about 200 feet below the mine area. These wastes consist essentially of carbonaceous shale and coal wastes removed from the mine. They are contained in a dump in excess of 60-80 feet wide by 30 feet high and estimated to contain between 3,000 to 5,000 cubic yards. The wastes have blocked the natural drainage in the coulee forcing recent runoff to either flow around the dump or through it. The drainage eventually merges with Cottonwood Creek about 700 feet west of the site.

The hillside over 300 feet north of the dump shows considerable evidence of subsurface seepage from the mine. Over 300 square yards of vegetation have been destroyed and much of the topsoil eroded away. The denuded area has a distinct ochre color resulting from the precipitation of iron. Much of the area is still saturated from the seepage although no measurable discharge or flow is evident.

The bench above the dump which fronts the lower working contains some wooden debris and an old cable reel from the hoist which either pulled coal from the mine or mine cars up the hillside. A large steam boiler is located in front of the former portals.

Anaconda Mine - Belt, Montana

The Anaconda Mine is located in the SW¼, Section 26, T19N, R6E about one-quarter mile southeast of the town of Belt, Montana. The site contains approximately 4 to 5 acres of mine wastes and

excavated material dumped along a moderately steep hillside on the west side of Belt Creek. A large open portal is excavated into the hillside about 100 yards downhill from the town of Belt's Water Storage tanks. The adit is about 30 feet wide by 8 to 10 feet high and is partially open for 20 to 30 feet. The adit was excavated into a massive sandstone of the Kootenai. The sandstone is highly fractured and jointed and numerous rock slabs have fallen from the roof and sides filling much of the adit area.

A continuous stream of acid mine discharge measured at over 150 gpm emerges from mine wastes about 200 feet from the mine entry. This stream runs downslope along a small ditch and eventually discharges into Belt Creek.

There is an estimated 5,000to 10,000cubic yards of mine wastes consisting of carbonaceous shale, coal, and cinders scattered along the face of the hillside between a county road along the hill and the Burlington Northern tracks. Considerable debris, wooden timbers, scrap metal and other associated waste are scattered throughout the waste piles.

GENERAL GEOLOGY AND HYDROLOGY

The geology of the Sand Coulee and Belt areas has been described by Goers (1968), Fisher (1909), Walker (1974), and Silverman and Harris (1967). Sand Coulee and Belt Creek lie in the Great Falls - Lewistown Coal Field. The principle seam which was the object of extensive mining in the first half of the twentieth century, is a thin seam at the top of the Jurassic Morrison Formation. The Morrison is primarily a thick bedded, light to medium gray-green mudstone, and is separated by the thin coal seam from the overlying Cretaceous Kootenai Formation. The Kootenai is a massive and competent sandstone which varies in thickness from 300 to 500 feet, and comprises the cap rock for the drainages near Belt, Centerville, and Stockett. The cap rock is visible as a prominent ledge along the valley sides.

The local geology of all project sites are as described above; Kootenai sandstone above, and in some cases adjacent to, the adit openings, and Morrison mudstone below the adits. A carbonaceous shale which overlies the coal seam in many places was described by Silverman and Harris (1968), and is evident in several of the adits. The carbonaceous shale material is the majority of the waste piles at the sites.

One of the project sites, Belt A, is located in the Belt Creek drainage basin, which is tributary to the Missouri River. The remainder of the sites are located in the Sand Coulee Creek drainage basin which totals 195 square miles in area. The Centerville "C" site is adjacent to Sand Coulee Creek, just north

of the town of Centerville. The Cottonwood Seeps and Stockett West Ridge sites are all in the Cottonwood Coulee drainage, which is tributary to Sand Coulee Creek. The confluence of Sand Coulee Creek and the Missouri River is about three miles south of the Great Falls. All sites are drained by ephemeral drainages, in which flow occurs primarily from spring snowmelt or intensive rainfall events.

Centerville "C"

Partial or total collapse of the adit has probably resulted in limited flooding of the mine workings and seepage along bedrock subcrops southwest of the mine adit. This seepage has in turn resulted in slumping along the hillside.

The waste dump should be removed and placed in a hydrologically less-sensitive location, such as on the toeslope of adjacent hillsides. This should also result in positive drainage and decreased infiltration through the material. Salvaged topsoil should be used as a cover, and revegetation should be implemented.

The collapsed adit should be replaced with a closure that allows free mine drainage while averting mine entry. A gravel filter base for adit backfill may suffice. Mine discharge should be concentrated and allowed to drain toward the creek. The flow path between the adit and the creek should be protected by gravel lining or riprap to protect against erosion.

By allowing the mine to drain, the acidic seeps along adjacent hillsides should abate. Reclamation and rehabilitation of the waste dump and slumps should be implemented in accordance

with recommendations of the soil scientist.

Stockett West Ridge

The site is the most significant of those contained in this project. It is sizeable, and it is adjacent to Stockett. Therefore, its potential influence on public health and safety must be considered significant.

Available topsoil in the immediate area should be salvaged where possible. All waste and debris should then be accumulated on the ridgetop, and contoured to provide positive drainage without simultaneous excessive erosion. Salvaged on-site topsoil and that obtained from nearby should be used to cover the recontoured waste. The objective is to hydrologically isolate or limit the waste from future atmospheric or precipitation contact.

To protect the cropped field from additional impacts due to deposition of waste debris, the eroded diversion should be redesigned, strengthened, and rehabilitated. With sucess of the ridgetop reclamation, however, this diversion should become increasingly unnecessary with time.

The eroded gully in the cropped field should be reclaimed in accordance with the soil scientist's recommendations.

Cottonwood "A"

This site contains two collapsed portals and associated carbonaceous shale waste piles. The waste piles are minor in extent and volume; however, the portals and dumps are situated just above the valley floor of a tributary to Cottonwood Creek. An abandoned slough of the creek extends in front of the waste

piles. Minor amounts of the waste material cover the bottom of the slough. The slough during an October, 1983 inspection also contained orange-colored standing water in several low spots. The standing water was probably a surface manifestation of shallow ground water in the alluvial sediments.

Any waste material that has accumulated in the bottom of the slough should be removed, and, together with the waste piles, be used to backfill the portals. Regrading, top-soiling, and re-vegetating of the waste-filled portals should be accomplished as described by the soil scientist. The valley floor should be re-contoured to provide positive drainage away from the site. The slough can be filled with soil material from a "high" area of the valley sediments which at present is situated between the slough and the main channel. Filling the slough will eliminate direct interaction of surface and ground waters at the site.

Cottonwood "B"

This site consists of two small partially collapsed adits and three substantive waste piles separated by what is apparently an old haul road. The waste piles are located just downhill and only a few hundred feet from the adits. The Problem Area Data Sheet (PV number MT-007) indicates that a collapsed, discharging adit was located 600 feet north of the above two adits. Field inspection determined that this latter site is not a collapsed adit and is, in fact, a natural headcut in a coulee tributary to Cottonwood Creek. A small spring with a pH of 2.9 and specific conductance of 3850 umhos/cm discharges at the base of the headcut. A slight oily film covered the orange colored water at the time of sampling. This AMD spring is probably the result of

ground water flowing through open workings beneath the adjacent hillside, dissolving oxidized iron, and then flowing the short distance through undisturbed Morrison Formation sediments to the surface at the base of the headcut. Alterations in local recharge conditions as a result of cropping patterns on the above bench may also contribute to the spring. Recent saline seep developments high on the hillside above the problem area also indicates that cropping patterns may be contributing to the spring development.

The two collapsed adits can be filled with the waste material. Soil cover and revegetation should be accomplished as suggested by the soil scientist. A local resident has indicated that he may want to use some of the waste shale as driveway cover at his home. This alternative use of the waste material should also be considered. Also, the old haul road should be regraded and reseeded to near original topography. No direct reclamation plan for the poor-quality spring is feasible. Changing cropping patterns on the bench may, in time, reduce local recharge; however, positive results from such a change would probably not be evident for several years.

Cottonwood "C"

This site consists of several collapsed adits, extensive waste dumps, an old haul road, and a large seep area. A large collapsed adit with a significant AMD located just to the south of this site is under study by the MBMG and is not part of the present reclamation project. Material in the waste piles should be used to fill the adit openings and then be regraded. The old

haul road should also be recontoured.

The seep will require more sophisticated reclamation techniques. The most feasible technique will be the installation of a subsurface drain to intercept and redirect ground water from the soil surface. A practical subsurface drain would consist of two to three perforated horizontal collectors perpendicular to the land surface slope and which are connected by "T's" to a single, solid pipe extending down slope to an excavation to a depth of two to three feet. The location and design of the drain discharge should be coordinated with MBMG's plans for the adjacent AMD. All reclaimed surface areas should be topsoiled, seeded, and lime-treated according to the soil scientist's recommendations.

SITE CHARACTERIZATION AND SOILS INVENTORY

Centerville "C"

This site consists of a filled portal, a large steep dump of waste coal, shale, and burned slag, and a complex of sidehill acid seeps to the south of the waste. The north-facing slope nearest the dump is slumping due to seep formation, and loss of vegetation on the steep slope.

The complex is situated in a steep drainage cutting 500 feet into the Kootenai caprock. Two branches of the drainage meet immediately below the waste pile making efforts at slope reduction in place difficult. The waste dump is at its angle of repose and represents a considerable erosion and mass wasting problem. Accelerated erosion from the site has led to the formation of a debris fan at the base of the slope where it meets the flat floodplain.

Filling of the adit has probably caused water to partially fill the mine workings. The hydrostatic head which has developed caused the formation of a series of three acid seeps on the west-facing slope south of the dump, in addition to the large seep adjacent to the portal. Opening the adit, and construction of a gravel-lined spillway may relieve the hydrostatic head allowing restoration of the seeps with application of 5 tons per acre of lime. Soils in the seep area are sandy loam in texture.

It is recommended that the waste dump be removed downslope and placed adjacent to the coalescing fan-terrace just north of the eroded debris on the floodplain below the dump. By extending this 15 foot high terrace onto the floodplain, the waste materials could be replaced in a less erodible landscape position. Eroded sediment on the floodplain bottom should also be placed in this fill area. A 6-inch veneer of soil should be spread across the fill. Soils can be obtained by excavating a suitable volume of soil from the fill area before placement of the wastes.

A rock-lined channel or buried conduit will need to be constructed to convey water from the portal to the base of the slope. Since the land upslope from the portal is in native range, there is little opportunity to reduce the flow of shallow ground water into the mine.

The mine waste has a pH of 4.7, sample 13A (Appendix B). Samples of related mine wastes in the area exhibited high boron contents (10 ppm), and low Cu/Mo ratios making them poor plant growth media. Investigation of the water-holding capacity of coal wastes (unpublished data) indicate that these materials hold 25 to 35% water at 0.3 bars of tension, and nearly the same quantity at 15 bars. Their water-holding capacity is less than 5 percent, hence making direct seeding on waste piles impractical. The acid wastes in the study area were surprisingly low in micronutrient and heavy metal levels. Heavy metal toxicity should not be a problem on lime-amended waste used for subsoil.

Many of the seep areas occur in soils with a large percentage of coarse fragments. Tillage and seedbed preparation on these seeps will be difficult. It may be necessary to use a dozer to prepare the site for hydromulching.

Stockett West Ridge

The Stockett complex occupies about three acres on the ridge between Cottonwood Creek and Number Five Coulee just west of the town of Stockett. A portal, numerous scattered waste dumps, and refuse from a municipal trash dump constitute the site. Serious erosion and acid runoff from the site have reduced or eliminated production from a grain field downslope.

Runoff from the site has increased due to steep slopes of the waste piles and to loss of vegetation from acid contamination. Massive regrading, cover-soiling, and liming will be required to restore the hydrologic balance. In-situ reduction of waste pile slopes in conjunction with placement of cover-soil will provide adequate reclamation.

Recovery of sufficient cover-soil for use on the site will be very difficult. Soils in the area are mapped in the Bitton-Roy complex and the Castner complex. Soils in the immediate vicinity are nearly all shallow to bedrock, and as such cannot be used for borrow of cover-soil unless they are to be buried by regraded waste. Soils along the slope to the southwest of the site appear to be somewhat deeper (Botton-like) than those in the site or to the northeast (Castner, rock outcrop).

Surface runoff from the site should be channeled so it does not spread across the wheat field below the site. The gully that has formed in the field should be filled, and contaminated soils should be limed (2.5 tons per acre). A drainage ditch above the field could be repaired and used to carry water around the cropped field.

Waste materials on the steep southeast-facing slope above Stockett should be removed upslope to the ridge-top where they can be graded and covered with soil material. Natural soils on the slope that are uncovered when wastes are removed will likely need to have 2.5 to 5 tons per acre of lime applied to them.

Upper Cottonwood "A" Site

This site consists of two small portals or test pits, and associated waste dumps just downslope of them. The dumps border a tributary to Cottonwood Creek just below a small stock pond. The spillway for the pond directs water into an abandoned channel of the Cottonwood tributary which runs across the toe of the waste embankment.

The waste materials should be hauled upslope and used to backfill the cavities around each portal. The regraded surface should then be covered with soil borrowed from upslope of the adits. Soils in this area include Bitton and Darret series. Darret soils are fine, mixed Typic Argiborolls. They are more than 40 inches deep, have more than 35 percent clay, and few rock fragments. Care should be taken that the area upslope from the fill is not oversteepened after soil removal. The disturbed area should be mulched to prevent erosion before establishment of a vegetative stand.

A small slightly raised terrace separates the Cottonwood Creek tributary from the slough where water flows at the base of the dump. Material from this terrace should be used to cover the base of the fill. In so doing, the channel carrying overflow from the pond will be moved east toward the Cottonwood Creek channel.

Upper Cottonwood "B" Site

The Cottonwood "B" site consists of a small area about 400 to 600 feet upslope from the feature identified as a "collapsed adit" in the AML National Inventory. Also included are three small mine waste piles south of the "adit".

Closer inspection revealed that the "collapsed adit" was in fact a natural escarpment obscured with brush. The seep area occurred above the coal cropline, and is believed to be a recently-formed saline seep which has developed from a crop-fallow recharge area atop of the bench. A change in cropping strategy would be the best approach to reclaim this seep. The three mine waste piles and scattered cinder wastes are located along the edge of an old haul road. The cinders are thought to be road fill and are presently being used locally for road surfacing. These waste materials should be used guardedly for this purpose due to the low pH, and high boron content of the material. Erosion of this material from the road into a ditch could cause further contamination of Cottonwood Creek.

Upper Cottonwood "C" Site

This site consists of a number of related problems. Several former portals exist on the site. One former adit located upslope from this site has a substantial flow of AMD which has ranged from 8 to 166 gallons per minute. pH was 2.4 to 2.9, and specific conductance 6826 micromhos per cm. Several waste dumps surround the adits. A contour ditch has been constructed along the side of the hill to carry the AMD to a roadside ditch, which

then carries the water another half mile before it enters Cottonwood Creek. In several places, water from the ditch has seeped downslope killing the vegetation and acidifying the soil. A large seep has developed on the north side of a small coulee that bisects the study area. An old haul road runs north and south along the slope. The southernmost adit with the AMD is excluded from consideration for this project in accordance to the DSL - AMR instructions for this site. Apparently this AMD site and discharge are being investigated by the MBMG.

The waste dump slopes should be regraded to reduce the slope gradient. Waste should be use to fill the collapsed area adjacent to the portal mouth. Bitton-like soil material should be used to cover the regraded waste. A source of soil immediately south and west of the waste dumps should be used. Soils on the knoll north of the dumps is too shallow to be used as a borrow area (Castner soils).

It is anticipated that some kind of drainage system will be needed to reduce the flow of water to the soil surface in the large seep. Horizontal drilling and placement of drain pipe, or establishment of a curtain drain upslope of the seep may be used to intercept subsurface water. A conventional agricultural drainage system with two main and several lateral branches placed at three feet in depth may also work. Ten tons of lime per acre should be spread on the seep and worked in with dozer ripping teeth. The soil is too rocky for adequate incorporation with conventional equipment.

Diversion of the AMD water directly to Cottonwood Creek through the coulee which bisects the side would reduce soil contamination by the water. The additional load of pollutants to the Creek may not be acceptable, however.

Anaconda Mine - Belt, Montana

The Belt site consists of a large collapsed portal above the road leading south of town from the elevator. Below the road is a series of waste dumps and gob from the mine. The site may have served as a coal loading tipple for the railroad. Tracks are located just below the site.

A majority of the waste should be hauled upslope and used to fill the portal cavity. A mound of natural soil occurs just north of the waste dumps (Bitton-like soils). This material could be used to spread over the site where waste materials were excavated, and also to veneer the filled portal. These soils are high in rock fragments, but will support a suitable vegetative stand.

Vegetation is growing in portions of the waste. The lime requirement for the waste materials (pH 4.5 field measurement) is assumed to be half that of sites in the Stockett area (20 tons per acre applied before cover-soil).

Replaced soil will be erodible on these slopes before establishment of a suitable vegetative stand, so mulching will be necessary.

A spring issues from the waste pile with a flow of about 20 gallons per minute. Care must be taken to insure that this

water does not come in contact with regraded waste materials. Conveyance of the water below the road in a culvert may be necessary. A stable channel or conduit should be constructed for conveyance of the water downslope toward Belt Creek.

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PLANT ECOLOGY - VEGETATION RECOMMENDATIONS

Evaluation of Belt-Sand Coulee Master Plan

The master plan report by Westech/Hydrometrics shows a great deal of effort in covering all aspects of reclamation of the abandoned mines of this region, and certainly demonstrates a great deal of effort expended in the literature review. However, the report falls short by trying to recommend only a few methods for a great variety of sites that each have rather specific characteristics that affect the materials, methods and cost of revegetation.

The vegetation types presented in the report were well sampled, but are too broadly defined for effective use in the reclamation of small sites. On grazed land, reclamation of small areas may cause congregation of livestock (due to higher palatability) if the post reclamation vegetation is significantly different from the surrounding landscape. The result could be trampling, soil erosion and loss of vegetation. This seems to have been overlooked or under evaluated by the master plan. The recognition of more narrowly defined vegetation types is necessary for the evaluation of this potential problem.

Another short-coming of the master plan is the low seeding rates that are recommended. The high seeding rates used by

DePuit and Coenenberg (1979) is now supported by others (eg. Doerr and Redente, 1983) and these findings make these higher seeding rates highly desireable for reclamation of this type. The general practice of broadcast seeding at twice the rate that would be drilled (now in general acceptance) also makes the seeding rate recommendations of the Westech/Hydrometrics report rather low.

It appears that there was minimal site specific investigation carried out for the master plan. An assumption seems to have been made that topsoil would be easily available for all sites, but on-site soil borrow is not readily available at all sites and its importation will add considerably to the cost of reclamation if the trucking distance is very far. At least three sites, Cottonwood "A", Cottonwood "B", and Stockett West Ridge will have problems obtaining sufficient on-site soil to adequately cover acid mine waste. This, along with the rocky nature of on-site soils, make drill seeding undesireable or impossible to achieve efficiently or economically. The most desireable method of broadcast seeding is by the use of the Brillion implement because of the packing both pre and post seed drop that provides some seedbed improvement. The use of this implement was not discussed in the master plan. Use of a large crawler tractor "Tracking" up and down the slope after broadcasting seed and mulch is also very effective.

Current vegetation of the sites immediately around or on the adit, slack or seep areas was altered by the mining that took place and is not representative of the pre-mining vegetation. The affect of the slope reconstruction and topsoiling that is to be done must also be considered, because it may create either

a drier or a more moist habitat than was there pre-mining, than is there now, or than the surrounding slopes vegetation. The placement of sites into one of the four vegetation types in the master plan appears to have underestimated these factors.

Engineering and Soils Prerequisites

Revegetation efforts can be undertaken only after acid mine discharge has been controlled, appropriate engineering actions taken to remove or bury mining debris and other materials unsuitable for plant growth, reshaping of the landscape has been accomplished, and soil replacement and slope stabilization from an engineering point have been accomplished.

At all sites, every effort should be made to keep the disturbed area (Mine disturbance, fill/soil borrow area, and equipment access roads) as small as possible. This is most important on sites were conventional tilling equipment cannot efficiently operate (25% slope; Long, 1981) or where the soil is too rocky to permit efficient conventional equipment operation.

At all sites where acid and/or carboniferous spoils are present, these spoils must be ammended by a surface covering of at least 20 tons per acre of lime prior to being covered with soil. This will allow amelioration of the acidity and help to present upward movement of toxic metals into the soil. Acid/carboniferous spoils should be covered by 24-36 in. of soil or combination of non-toxic overburden and soil if at all possible. Redente, et al (1982) demonstrated that 36 in. of soil or 24 in. of soil on top of a capillary barrier was required to produce the best above-ground production. Schafer (1979) recommends

30-40 in. of cover-soil be required over material unsuitable for plant growth either because of acidity/toxicity or high rock content, a minimum soil depth of 12 in. is recommended.

Site specific recommendations for engineering and soils consideration are provided in the following sections.

SITE SPECIFIC VEGETATION - SOILS RECOMMENDATIONS AND ENGINEERING CONSIDERATIONS

Centerville "C"

This site is divided into four sibsites in order to facilitate clarity of the recommendations: Adit/Slack Subsite, Seep/Slump Subsite, Minor Seeps Subsite and Slack Burial Subsite.

Adit/Slack Subsite

The slack piles on this slope should be removed to restore the original slope profile. Soils borrow may be obtained from the high stream bench at the base of the slope. The slack can be used to reconstruct and extend the bench and then covered with soil and revegetated. This area is designated as the Spoils Burial Subsite.

After the slack has been stripped from the slope, liming and soil covering as recommended herein should be completed. Shallow contour furrows created during application of the soil will assist in soil erosion reduction and facilitate a good seeding environment. An alternative method would be the use of a large crawler tractor to "track in" the seeded and mulched surface. Terracing of the slope should not be necessary but would be desireable. Planting should be accomplished by hydroseeding/hydromulching.

Seep/Slump Subsite

The slope to the south of the slack piles and adit should

not be physically altered in any way. Although some slumping has already occurred, the remaining vegetation, both live and dead, are providing considerable slope stability and any damage to this slope may result in a less desireable condition. Care should be taken to insure that the base of the slope where it joins the Adit/Slack subsite slope be left intact and not undercut by the slack removal manipulations. This could cause additional slope instability and increase the slumping of the slope. Preservation of the existing soil profile on this slope is also a benefit of leaving the slope intact.

The slope should be surface limed at a rate of 10 tons per acre and applied using the same equipment used to hydroseed the site.

Minor Seeps Subsite

The minor seeps to the south of the Seep/Slump Subsite should be limed at the rate of 20 tons per acre and the lime incorporated into the soil by disking or bulldozer ripping on six inch centers to a depth of 6 inches. If sufficient soil borrow is available, a cover of 6 inches of soil will facilitate plant growth. Harrowing should follow soil spreading to prepare an adequate seedbed. If soil borrow is in short supply, smoothing of the limed surface material on site should be accomplished by harrowing if not too rocky, or by any bulldozer implement that will create a relatively smooth seedbed.

Planting of this site should be by broadcast seeding followed by "tracking in" with a large crawler tractor or by hydroseeding if not cost prohibitive.

Slack Burial Subsite

Slack burial should follow the recommendations prescribed above. Since the slope angle is low, the seedbed should be prepared by disking and harrowing with conventional tillage equipment. Planting should be by drill seeding.

Stockett West Ridge

A pit should be excavated and all trash and carboniferous slack from the site buried under at least 40 inches of cinder or excavated rock debris just down-slope from the current trash dump. The entire area can then be reshaped and 20 tons per acre of lime spread over the surface and worked into a depth of 6 in. by chiseling or ripping on 6 inch centers. Multiple passes on two foot centers will approximate 6 inch centers.

Because this site appears to have little soil borrow available, any soil covering that can be obtained is desireable. It will be difficult to establish a good stand of vegetation on this site, due to its location on the ridge top and the existing rocky soils. The deeper the soil cover, the better the chance of achieving good revegetation. Six inches of soil cover is an absolute minimum.

The majority of the area to be reclaimed is well within the limits of slope angle to permit use of conventional tillage equipment. Disking and harrowing should follow soil spreading. Planting will be accomplished by broadcast seeding using a Brillion seeder. A conventional tractor pulling this seeder should be able to negotiate the steepest parts of the site (estimated to be a 35% slope) because the implement is pulled directly up the

fall line of the slope. Any areas too steep for the equipment are small and can be hand broadcast and "tracked in" with a large crawler tractor.

Upper Cottonwood "A"

This site has been separated into the two subsites because of the significant differences between two portions of the site: Adit Subsite, and Bottomland Subsite.

Adit Subsite

All carboniferous slack should be buried per the following recommendations: 20 tons per acre of lime should be applied and worked into the surface to a depth of 6 inches by chiseling or ripping on 6 inch centers. Multiple offset passes of two foot rips will approximate 6 inch centers. The surface should then be harrowed to provide a better seedbed. Slope reshaping and soil application present no problems. The low slope angle will allow disking and harrowing with conventional tillage equipment.

If the soil cover is not too rocky, seed can be drilled. If the rock content in the soil is too high, a Brillion broadcast seeder should be employed. "Tracking in" of the surface with a large crawler tractor should follow the seeding.

Bottomland Subsite

The area along the creek bottom that may be flooded during spring runoff should contain no buried slack. Soil material in this area should be in good condition and should be stripped and reapplied after site reshaping. This soil covering should be disked and harrowed prior to planting by drill seeding.

Upper Cottonwood "B"

All slack material should be exported or buried and covered by non-slack spoils or soil. The soil should be spread over the site after the following:

Application of 20 tons per acre of lime should be applied and worked into the soil to a depth of 6 inches by chiseling or ripping on 6 inch centers. Multiple offset passes of two foot rips will approximate 6 inch centers. The surface should then be harrowed to provide a more suitable seedbed. Seeding should be by a Brillion broadcast seeder and "tracking in" with a large crawler tractor.

Because this site appears to lack sufficient soil borrow material, the cover for the slack may have to be subsoil material located on-site. However, a suitable soil covering of at least 6 inches should be applied to provide a proper plant growth environment.

Disking and harrowing should follow final soil application. Planting should be accomplished by a Brillion broadcast seeder and "tracking in" with a large crawler tractor.

Upper Cottonwood "C"

This site does not appear to have sufficient soil borrow. If sufficient soil is available, soil should be spread over the site after following the recommendations provided. The addition of soil would provide a much better plant growth medium.

Application of 20 tons per acre of lime should be applied and worked into the soil to a depth of 6 inches by chiseling or ripping on 6 inch centers. Multiple offset passes of two foot rips will approximate 6 inch centers. The surface should then be harrowed to provide a more suitable seedbed. Seeding should be by a Brillion broadcast seeder and "tracking in" with a large crawler tractor.

The slack piles and the old road covered with slack should be buried and covered by non-slack spoils or soil as prescribed herein and then limed and incorporated as described previously.

Belt "A"

Adit Subsite

Borrow areas and equipment access roads should be located on the slope to the north of the adit. The slope to the south of the adit has a shallow soil and is a snow drift accumulation area which will likely add to the erosion potential of that area. The curvature of the slope into the adjacent gully also complicates the reclamation effort. The high production of shrubs on this part of the slope would also require additional costs for seedling stock to plant this part of the slope.

This subsite will require hydroseeding/hydromulching because of the steep slope angle (40% as measured by clinometer). Conventional tillage equipment cannot be used, therefore creation of shallow contour furrows during application of topsoil is recommended to assist in controlling erosion. An alternate method would be "tracking" up and down the slope with a crawler tractor prior to hydroseeding/hydromulching. Terracing of this slope should not be necessary.

Slack Subsite

This subsite can be considered as all the remaining area from the base of the adit slope on the west side of the road disecting the site, to the base of the slack piles east of the road. After burial of the slack piles, reshaping of the subsite should produce a slope without any abrupt changes in slope angle and the steepest portion of the slope should be less than 30%. If this can be accomplished, conventional tillage and planting equipment can be employed for reseeding. Liming of slack spoils and soil depth needs as stated herein should be observed.

If the slope angle cannot be kept below 30%, seeding of this site will have to be accomplished by broadcast seeding and

crawler tractor "tracking" up and down the slope.

CURRENT VEGETATION AND SEEDING RECOMMENDATIONS

Vegetation as described by Kuchler (1975), Ross and Hunter (1976), and Mueggler and Stewart (1980, all provide views with respect to potential species composition for seeding on these sites. Each of these publications is directed primarily at climax communities, i.e., communities not drastically altered by grazing or other major disturbances. However, all the sites concerned with this study are currently grazed and the post reclamation land use will also be grazing (Westech/Hydrometric, 1982). Therefore, these sites cannot be reasonably considered as potential climax community candidates.

The Westech/Hydrometrics (W/H) report classifies the vegetation of the region into only four types. However, each site has its own specific composition and any reclamation recommendations should take these into account. Reclamation may also result in site characteristics that are drier or wetter than the surrounding vegetation. Vegetation prior to mining may have been very different than post-mining vegetation because of altered drainage patterns, reduced soil (cover, subsoil water additions, etc.

The species selected for revegetation should be compatable with the surrounding vegetation as well as reflect the expected environmental changes. If the seed mix contains too many highly palatable species, livestock concentration on the revegetated site after release from deferment may result in excessive tramping and overgrazing with a consequent accelerated erosion and

loss of revegetation objectives. On the other hand, species selected for revegetation should be heavily directed toward rapid, easy establishment and good soil stabilization. These objectives should all be balanced in the final species selection, and this is generally provided by a broad spectrum of species.

DePuit and Coenenberg (1979) demonstrated that seeding rates as high as 40 to 80 pounds per acre for drilled and broadcast seeding, respectively, resulted in increased stand productivity over smaller seeding rates. Broadcast seeding (at twice the drilled seeding rate) had slightly higher productivity than did drill seeding and that native species were slightly favored over introduced species. They also demonstrated that increased seed mix diversity resulted in an increased diversity of the resulting community without detriment to stand productivity. Doerr and Redente (1983) also found that broadcast seeding at twice the drill rate resulted in no significant difference between the resulting above-ground production of the two seeding method plots. They also found that fertilization reduced forb production but that broadcast seeding favored forb production over the drilled method. Introduced forbs were favored over native forbs in all cases. Fertilization initially increased grass yields, but after four years, no difference between fertilized and unfertilized plots could be detected.

The seed mixes and seeding rates presented for each site were selected after consideration of the composition of the adjacent vegetation, the results of the above research studies and

the recommendations of many other studies (esp. Long, 1981; Thames, 1977; EPA, 1975; Shaw and Cooper, 1973). The seed mixes are designed to provide species for easy establishment, good seedling vigor, rapid growth and good soil stabilization while still providing diversity, mixed palatibility, and similarity to adjacent vegetation. All seeding rates used in this report are Pure Live Seed rates. Actual seeding rates can only be determined after seed has been purchased and purity and germination are known.

Changes in community composition (as a result of species competition) are to be expected through the grazing deferment period. After the site is released from deferment, additional compositional changes will occur as grazing provides a new selection pressure for the plant community to adjust to.

Nitrogen fertilization recommendations are deliberately low to encourage grass establishment without encouraging weed growth. The fertilizer used on this project should be of the slow release type.

Nomenclature of grass species follows Hitchcock and Chase (1971); all other species follow Hitchcock and Cronquist (1973). Symphoricarpos albus and S. occidentalis are considered to be ecologically equivalent in this region. The Appendix lists common names for species that are used in this report. Varietal recommendations are from Montana Agric. Exp. Sta. (1970) and Long (1981). Legumes should be purchased from sellers that supply the appropriate innoculant with the seed. Long (1981)

should be consulted in addition to the W/H report for listings of seed dealers in the region.

In the following section, current vegetation, recommended seed mix, seeding rate and seeding method, fertilization rate and mulching requirements are presented for each site/subsite.

Centerville"C"

This site has been divided into four subsites because of different habitat conditions and consequent treatments. The subsites are: Adit/Slack Subsite, Seep/Slump Subsite, Minor Seeps Subsite, and Slack Burial Subsite.

Adib/Slack and Seep/Slump Subsites

The slopes around the adit are primarily shrubby and are dominated by R. trilobata, P. virginiana, C. douglasii, S. occidentalis and Amelanchier alnifolia. The grass understory is sparce and composed of A. spicatum, P. pratenis and Festuca idahoensis; Calamovilfa Longifolia occurs in some areas.

Caution should be exercised when working on this slope because of an understory cover of Poison Ivy (Rhus radicans). Brush should not be burned because inhalation of toxic fumes could cause severe respiratory problems. Any brush removed during reclamation should be buried to avoid potential risk to humans. The close proximity of the site to the town of Centerville makes burial particularly desirable.

Reclaiming the adit/slack subsite will result in a habitat more conducive to grass growth because of the deeper soils that will be present post reclamation. For this reason, the seed mix is directed toward a grass community. Shrub seed has been

provided in the mix to provide a seed source for those shrub niches that remain after slope reconstruction. Planting of shrub seedling stock is not recommended.

The Seep/Slump Slope subsite should be left intact to take advantage of the slope stability provided by the living and dead vegetation that is currently there. Hydroseeding/hydromulching over the existing vegetation should help reestablish grasses that have largely been killed by the acid seep water.

Seeding of these two subsites should be performed in the late fall to reduce the possibility of rain erosion. Table 1 presents the seeding mix for use on both subsites. Seeding should be by the hydroseeding/hydromulching method because of the steep slope angle. Seed, fertilizer and mulch can be applied all in one application. Fertilizer should be applied at a rate of 20 to 40 pounds per acre of 10-55-0 (as P_2O_5) slow release fertilizer. Wood fiber mulch should be applied at the rate of 2,000 pounds per acre and should not contain plastic emulsions or organic seed additives.

The mulch should be mixed first, then fertilizer and seed mixed with the mulch within 20 minutes of actual application to the slope. Inoculation of legumes should be accomplished prior to their addition to the mulch mix. Seeding should be conducted in the late fall (after October 15) to avoid rain erosion problems and to take advantage of early spring growth prior to spring rains.

Jute netting should be applied over the hydromulching in the

drainageway between the Adit/Slack Slope and the Seep/Slump Slope and in the drainageway between the Adit/Slack Slope and the hillslope to the north of the site. This will help prevent erosion in these two drainageways while vegetation is establishing. The jute netting should be stapled to the ground so that shifting of the netting does not occur. The jute netting will eventually decay, adding organic matter to the soil.

TABLE 1

CENTERVILLE "C" SEED MIX AND SEEDING RATES(AS PURE LIVE SEED)

SPECIES	Adit/Slack Slope and Seep/Slump Slope		Minor Seeps Slope		Slack Burial Slope	
	Lbs/acre	PLS/Ft^2	Lbs/acre	PLS/Ft^2	Lbs/acre	PLS/Ft^2
Grasses						
Agropyron smithii	5.0	13.1	5.0	13.1	5.0	13.1
Agropyron riparium 'Sodar'	2.0	7.4	1.0	3.7	1.0	3.7
Bromus inermus 'Lincoln'					2.0	6.4
Bouteloua gracilis			1.0	16.7	0.5	8.4
Stipa viridula 'Green Stipa'	3.0	11.4	1.0	3.8	2.0	7.6
Stipa comata			2.0	5.2		
Oryzopsis hymenoides 'Nezpar'	1.0	3.7	1.0	3.7		
Legumes						
Astragalus cicer	0.5	1.5	0.5	1.5	1.0	3.0
Medicago sativa					0.5	2.4
Shrub						
Rosa woodsii	0.5	2.6				
Mix Totals	12.0	39.7	11.5	47.7	12.0	44.6

Seed rates shown are for Broadcast Seeding. If seed is Drilled, rates should be cut in half.

Minor Seeps Subsite

The vegetation of this slope is grass dominated and is principle A. spicatum, P. pratensis and Festuca idahoensis. Calamovilfa Longifolia and B. gracilis are present in some areas.

Broadcast seeding with a Brillion seeder or by hand broadcasting will be the best planting method for this area. The seedbed should be prepared by harrowing or another method that will smooth the surface for seed application. Late fall planting will be best, both from a vegetation establishment point and because seeding on the remainder of the site is also recommended for fall planting.

Slow release fertilizer should be applied at the rate of 20 and 40 pounds per acre of nitrogen and phosphorus, respectively. After planting and fertilization,4,000 pounds per acre of straw mulch should be applied to reduce erosion and preserve soil moisture.

Hydroseeding/hydromulching of this subsite is another seeding possibility if it fits in economically with the overall site reclamation plan. If this method is adopted, the seed mix need not be altered from that for broadcast seeding. Fertilizer and mulch requirements would be identical to those presented for the Adit/Slack Subsite.

Stockett West Ridge

The Stockett West Ridge is dry grassland dominated by A. spicatum, A. smithii, B. gracilis, K. cristata, Muhlenbergia cuspidata and P. pratensis. Artemisiafrigida, Gutierrezia sarothrae, Linum perenne and Chrysopsis villosa are the most common forbs. Shrubs are not common on this dry ridge.

Table 2 presents the seed mix and seeding rates for this site. Emphasis is placed on drought tolerant grasses. The Legumes should be innoculated with the appropriate bacteria prior to seeding.

Late fall broadcast seeding using a Brillion seeder should be used on this site. This seeder should be pulled up the slope rather than on the contour. This will produce shallow contour furrows as the seed is broadcast and help to capture precipitation and reduce erosion. The seeding equipment should be able to operate on all parts of this site, but if any portion is too steep for the equipment, the seed should be broadcast by hand for those areas.

Slow release fertilizer should be applied at the rate of 20 and 40 pounds per acre of nitrogen and phosphorus, respectively. After planting and fertilization, 4,000 pounds per acre of straw mulch should be applied to reduce erosion and preserve soil moisture.

Sprinkler irrigation during the first year should be considered. This site has little soil borrow available and because of its position on the ridgecrest, it will probably be the driest of all the sites. The close proximity to the town of Stockett is the only reason that irrigation might be considered.

Table 2 presents the seed mix and seeding rates for this site. Emphasis is placed on drought tolerant grasses. The Legumes should be innoculated with the appropriate bacteria prior to seeding.

Because of the high rock content of the soil on this site, seeding should be by a Brillion boradcast seeder after the site has been smoothed by harrow or similar implement. Late fall planting will provide the best potential for good seedling establishment.

Slow release fertilizer should be applied at the rate of 20 and 40 pounds per acre of nitrogen and phosphorus, respectively. After planting and fertilization, 4,000 pounds per acre of straw mulch should be applied to reduce erosion and preserve soil moisture.

TABLE 2

STOCKETT WEST RIDGE, COTTONWOOD "C", AND COTTONWOOD "B"

SEED MIXES AND SEEDING RATES (AS PURE LIVE SEED)

Species	Stockett West ridge		Cottonwood B and Cotonwood C	
	Lbs/acre	PLS/Ft^2	Lbs/acre	PLS/Ft^2
Grasses				
Agropyron smithii	4.0	10.4	4.0	10.4
Agropyron riparium	2.0	7.4	2.0	7.4
Bouteloua gracilis	1.0	16.7	1.2	20.0
Elymus canadensis	1.0	2.4		
Stipa comata			2.0	5.2
Oryzopsis hymenoides	1.0	3.7		
Legumes				
Astragalus cicer	0.5	1.5	0.5	1.5
Mix Totals	9.5	42.1	9.7	44.5

Seed rates shown are for Broadcast Seeding. If seed is Drilled, rates should be cut in half.

Cottonwood "A" - Adit Slope Subsite

This east facing slope is a more moist habitat than the other Cottonwood sites and is a mesic grassland. The dominant grasses are A. spicatum, A. smithii, P. pratensis and S. viridula. A. frigida is the most common forb and S. occidentalis is the most common shrub. Other shrubs that are currently present are there because of the mining activity. Reclamation of this site will return the habitat conditions that favor mesic grassland.

The seed mix and planting rates are presented in Table 3. This subsite can be planted in April, May, August or after mid-October. An August planting date may be best if the Bottomland subsite has the potential to be flooded during spring runoff.

The seedbed should be prepared by disking and harrowing. Seed should be drilled if the soil is not too rocky. If drilling is not possible, broadcast seeding with a Brillion seeder is the preferred method of planting. Seeding rates should be doubled if broadcast seeding is required.

TABLE 3

COTTONWOOD "A" SEED MIX AND SEEDING RATES (AS PURE LIVE SEED)

Species	Adit Slope		Bottomland	
	Lbs/acre	PLS/Ft^2	Lbs/acre	PLS/Ft^2
Grasses				
Agropyron smithii	5.0	13.1	4.0	10.4
Agropyron riparium	2.0	7.4	1.0	3.7
Bromus inermis			2.0	6.4
Elymus cinereus			1.0	3.5
Stipa viridula	3.0	11.4	2.0	7.6
Boteloua gracilis	0.5	8.4		
Legumes				
Astragalus cicer	0.5	1.5	0.5	1.5
Medicago sativa			0.5	2.4
Shrub				
Rosa woodsii			0.5	2.6
Mix Totals	11.0	41.8	11.5	38.1

Seed rates shown are for Broadcast Seeding.
If seed is Drilled, rates should be cut in half.

Fertilization should be 20 and 40 pounds per acre of nitrogen and phosphorus, respectively, and would best be applied as 200 pounds per acre of slow release 10-55-0 (as P_2O_5). The seeded slope should be covered with 3,000 pounds per acre of straw mulch to reduce erosion and improve soil water retention.

Bottomland Subsite

This subsite is dominated by the introduced grasses B. inermis, P. pratensis and Phleum pratense. The native buchgrasses S. viridula and Elymus cinereus and the shrub S. occidentalis are common.

August planting of this site is recommended to take advantage of germination from fall rains so that seedlings are established prior to any potential of being flooded by spring runoff in this drainage. However, planting can be conducted in April, May, August, or late fall as best fits the overall reclamation plan.

Seedbed preparation by disking and harrowing should be followed by drill seeding using the seed mix and rates presented in Table 3. Fertilization 20 and 40 pounds per acre of nitrogen and phosphorus, respectively, should be followed by application of 3,000 pounds per acre of straw mulch for erosion protection, soil moisture retention, and for an improved germination environment.

Upper Cottonwood "B"

The vegetation type of this site is dry grassland dominated by S. comata, B. gracilis, and A. smithii. Carex

filifolia, K. cristata and Poa sandbergii are common grass associates. A. frigida and G. sarothrae are the common forbs. Shrubs are absent on this site.

Table 2 presents the seed mix and seeding rates for this site. Emphasis is placed on drought tolerant grasses. The legumes should be innoculated with the appropriate bacteria prior to seeding.

Because of the high rock content of the soil on this site, seeding should be by a Brillion broadcast seeder after the site has been smoothed by harrow or similar implement. Late fall planting will provide the best potential for good seedling establishment.

Slow release fertilizer should be applied at the rate of 20 and 40 pounds per acre of nitrogen and phosphorus, respectively. After planting and fertilization, 4,000 pounds per acre of straw mulch should be applied to reduce erosion and preserve soil moisture.

Upper Cottonwood "C"

The vegetation type at this site is dry grassland dominated by S. comata, B. gracilis, and A. smithii. Carex filifolia, K. cristata, and Poa sandpergii are common grass associates. A. frigida and G. sarothrae are the common forbs. Shrubs are absent on this site.

BELT "A"

This site has been divided into two subsites because of the differences in type of habitat and post reclamation management.

Adit Subsite

Vegetation around the adit is dominated by shrub species, particularly Prunus virginiana, Rhus trilobata, Symphoricarpos occidentalis and Crataegus douglasii. The abundance of shrub cover is largely due to bedrock at or very near the soil surface. The grass understory is predominately Poa pratensis and Agropyron smithii. Caution should be taken whenworking on this slope because Poison Ivy (Rhus radicans) is present as a ground cover in many areas. Brush removed during reclamation should be buried and not burned (to avoid inhalation of the toxic oils present even in the stems of this species).

Following reclamation, the habitat will more closely resemble the slope to the north of the adit area. This will be the result of the deeper soil applied to the site than currently exists in the shrub dominated area. As a consequence,grasses will be favored over shrubs. The area to the north of the adit presents a definite grassland aspect and is dominated by P. pratensis, A. spicatum and A. smithii, Stipa comata, S. viridula and Koeleria cristata are also present. S. occidentalis, R. trilobata and some P. virginiana are present but do not dominate.

The seed mix and seeding rate for this subsite is presented in Table 4. Good seed germination and seedling survival were demonstrated with the shrub species used in this mix (Harvey, unpublished data) and therefore, planting of seedling stock is

TABLE 4

BELT "A" SEED MIX AND SEEDING RATES (AS PURE LIVE SEED)

Species	Adit Slope		Slack Slope	
	Lbs/acre	PLS/Ft^2	Lbs/acre	PLS/Ft^2
Grasses				
Agropyron smithii	5.0	13.1	5.0	13.1
Agropyron riparium	2.0	7.4	1.0	3.7
Bromus inermis			2.0	6.4
Stipa viridula	3.0	11.4	2.0	7.6
Oryzopsis hymenoides	1.0	3.7		
Legumes				
Astragalus cicer	0.5	1.5	1.0	3.0
Medicago sativa			0.5	2.4
Shrub				
Rosa woodsii	0.5	2.6		
Mix Totals	12.0	39.7	12.0	44.6

Seed rates shown are for Broadcast Seeding. If seed is Drilled, rates should be cut in half.

felt to be an unnecessary expense.

Seeding for this subsite should be by hydroseeding/hydromulching or broadcast seeding and "tracking in" with a large crawler tractor because of steep slope angle. Seeding should be done after October 15 to reduce the chance of rain erosion damage. Seed, fertilizer, and mulch can all be applied in one application. Fertilizer should be applied at a rate of 20 and 40 pounds per acre of nitrogen and phosphorus, respectively. This may be applied as 200 pounds per acre of 10-55-0 (as P_2O_5) slow release fertilizer. Mulch should be wood fiber and applied at the rate of 2,000 pounds per acre. No plastic emulsions or organic seed additives should be used with the mulch.

The mulch should be mixed first, then fertilizer and seed mixed with the mulch within 20 minutes of actual application to the slope. Inoculation of legumes should be accomplished prior to their addition to the mulch mix.

Slack Subsite

Current vegetation of the site from the base of the adit slope to the base of the slack piles is dominated by introduced grasses. The roadside vegetation all along the roadway is mostly Bromus inermis and P. pratensis. Bouteloua gracilis, P. compressa and A. smithii occur on the drier microsites along with a variety of forbs. S. occidentalis and Rosa arkansana are found in the wetter areas along the roadside.

Post reclamation use of this subsite will not ential grazing, but the road disecting the subsite will provide added runoff and increase the importation of weed seed. For these reasons

the seed mix has a high proportion of introduced rhizomatous grasses to encourage rapid formation of a dense grass community.

Late fall (after October 15) or early spring (April to May) seeding of the subsite is acceptable, but late fall seeding is probably more economical because it will coincide with planting of the adit slope subsite. Contour disking and harrowing should be followed by conventional drilling.

Slow release fertilizer should be applied at the rate of 20 to 40 pounds per acre of nitrogen and phosphorus, respectively, and may be applied as 200 pounds per acre of 10-55-0 (as P_2O_5).

Three thousand pounds per acre of straw mulch should be applied following planting and fertilization.

If the post shaping slope angle is greater than 30%, seeding by broadcast will be necessary. If the high angle slope areas are small, hand broadcast seeding of those areas and drilling of the slopes less than 30% should be done. If large areas of greater than 30% slopes occur, broadcast seeding with a Brillion seeder pulled up the fall line should be employed wherever possible. All slopes exceeding 35% will have to be seeded by hand broadcast followed by "tracking" up and down the slope with a crawler tractor, or by hydroseeding.

POST RECLAMATION RECOMMENDATIONS

All sites/subsites should be deferred from grazing for a minimum period of three years in order to ensure a good vegetation establishment. Fencing of the site will probably be required so that the landowner's entire pasture does not have to be deferred from grazing.

Site inspection the spring following planting should occur at least once a month during the period March through June to ensure that any erosion can be detected well before any severe damage occurrs. Vegetation establishment can be evaluated at these visits and the need for any reseeding can be evaluated within sufficient time for August of late fall seeding amendments. Unless establishment has been extremely poor, reseeding should be done by hand broadcasting. This will avoid any damage to established plants from mechanical planting equipment.

Annual site inspection should be performed during the following years of deferment in order to establish the proper time for release from deferment. Annual site inspection for two years following release will ensure that overgrazing, trampling, etc. of the site are not jeopardizing the goals of the reclamation effort.

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Appendix. Scientific and common names of plant species used in this report. Grasses follow Hitchcock and Chase (1971), all others follow Hitchcock and Cronquist (1973).

Scientific Name	Common Name
Achillea millefolium	Yarrow
Agropyron dasystachyum	Thickspike Wheatgrass
Agropyron riparium	Streambank Wheatgrass
Abropyron spicatum	Bluebunch Wheatgrass
Agropyron smithii	Western Wheatgrass
Amalancier alnifolia	Shadscale (Serviceberry)
Artemisia frigida	Fringed Sagewort
Astragalus Cicer	Cicer Milkvetch
Bouteloua gracilis	Sideoats (Blue) Grama
Bromus inermis	Smooth Brome
Calamovilfa Longifolia	Prairie Sandreed
Carex filifolia	Needle-Leaf Sedge
Chrysopsis villosa	Hairy Golden-Aster
Crataegus douglasii	Black Hawthorn
Elymus canadensis	Canadian Wildrye
Elymus cinereus	Giant Wildrye
Festuca idahoensis	Idaho Fescue
Gutierrezia sarothrae	Broom Snakeweed
Hedysarum boreale	Northern Sweetvetch
Koeleria cristata	Prairie Junegrass
Linum perenne var. lewisii	Wild Blue Flax
Lupinus sericeus	Silky Lupine
Medicago sativa	Alfalfa
Melilotus officinalis	Yellow Sweetclover
Muhlenbergia cuspidata	Plains Muhly
Petalostemum purpureum	Purple Prairie Clover
Phleum pratense	Timothy
Poa compressa	Canada Bluegrass
Poa pratensis	Kentucky Bluegrass
Poa sandbergii	Sandberg's Bluegrass
Prunus virginiana	Common Chokecherry
Psoralea tenuiflora	Slender-flowered Scurf-Pea
Rhus radicans	Poison Ivy
Rhus trilobata	Skunkbush Sumac
Rosa arkansana	Arkansas Rose
Stipa comata	Needle-and-Thread
Stipa viridula	Green Needlegrass
Symporicarpos albus	Common Snowberry
Symphoricarpos occidentalis	Western Snowberry
Thermopsis rhomoifolia	Round-Leaved Thermopsis

Centerville 'C'

The Centerville 'C' site presents two significant environmental and safety hazards. The mine discharge and seepage are slowly eroding away the north side of the coulee and a substantial portion of the hillside adjacent to the site. Discharge from the mine, estimated to be about 6 - 8 gpm, will probably increase with time. Insufficient containment of the discharge and inadequate control or non-elimination of the seepage will result in increased and accelerated erosion and sloughing of the hillside. This will destroy most of the vegetation along the hillside and will deposit a significant quantity of contaminated soils into the stream bottom.

The large waste dump and cinder pile along the hillside below the former mine is unstable and will continue to wash out during periods of high runoff and snowmelt. These washed out mine wastes will contribute additional unsuitable material along the base of the hill and will gradually destroy the vegetation along the stream bottom.

The waste pile and eroding hillside are a potential danger and become increasingly unstable and hazardous as the saturation increases. Large mud flows could develop, or blocks of the hillside may fail, jeopardizing the lives of persons or livestock in the vicinity of the slides. The existing waste dump should be removed and the material dispersed along the base of the hill and revegetated. The drainage along each coulee should be restored and the sides stabilized.

The steep slopes adjacent to and below the mine openings should be regraded to match existing contours after the waste materials have been removed. These slopes should be covered with a thin veneer of topsoil. The areas can then be revegetated using hydromulch application of mulch, seed, and fertilizer. The topsoil used will have to be imported and should be obtained from a borrow source at the closest possible location to the site.

Stockett West Ridge

Almost 5 acres of land have become unproductive due to the large quantity of mine wastes dumped along the ridge. The site was subsequently used as a garbage dump and trash disposal area by the town of Stockett, Montana. The large accumulation of coal waste, cinders and trash form the western edge of Stockett and are a visual blight to the town. The disturbed area also restricts any future expansion of the town, as the west edge is the only area available for future development. Much of the waste consists of carbonaceous shale and coal and is susceptible to spontaneous combustion. This is indicated by the presence of numerous cinder piles which are evidence of former fires. This fire potential is a serious threat to the town of Stockett due to the close proximity of these wastes to the major residential area of town. Continuous seepage of mine discharge from wastes along the eastern side of the ridge is acidic and contains high sulfate and iron levels. This seepage flows through the main area of town before it finally discharges into Cottonwood Creek.

The continued erosion and redeposition of mine wastes from the west side of the ridge are encroaching on highly productive farm land along the base of the ridge. Runoff from the hill is also creating a large gully across the farm land requiring the farmer to work around the gully. It is apparent that uncontrolled runoff from the west side of the ridge will gradually widen and deepen the gully resulting in a greater loss of farm ground.

The entire disturbed area will require a significant removal and disbursement of the mine wastes to minimize the effect of the runoff and erosion and to restore the productivity of this site.

The existing seepage along the eastern side of the ridge will have to be intercepted and confined to a ditch or pipeline to reduce the wide spread saturated face and the consequent destruction of soil and vegetation. The interception and pipeline should probably be located below the subsurface to eliminate the potential from further erosion.

The lack of adequate soil to amend or cover the waste will necessitate burial of some of the waste material. Remaining mine wastes will be dozed or transported to the crest of the hill and graded to its angle repose in order to achieve the most stable hydrologic configuration. This will minimize the runoff effects and eliminate erosion and washing out of the material.

Upper Cottonwood "A"

The two former entry and portal areas of the mine

should be backfilled using the existing wastes below each portal. This would eliminate the potential polluting effects of precipitation percolating through these wastes to the tributary stream and to Cottonwood Creek.

Filling the excavated portal sites, covering the fill material with soil, and restablishing the vegetation will eliminate the collection of runoff and snowmelt and reduce the potential of this water to migrate through the subsurface and recharge to the ditch at the toe of the hillside.

The former channel of the stream should be cleaned of all toxic material and then backfilled with good soil. The channel should be filled and then graded to force all runoff and/or high stream flow to remain in the existing channel. Toxic material should be removed and buried in the former portal areas before backfilling using the waste.

The high mound of natural soils located between the former channel of the creek and the existing channel can be lowered and the materials used to backfill and cover the old channel. The ground surface should be sloped toward the existing creek.

Upper Cottonwood "B"

The two open portals and partially open adits are a significant threat to anyone venturing into the adits. The roof structure is highly fractured and is in a continual stage of failure and falling rock. The large pile of carbonaceous wastes and coal are a fire hazard and in addition probably generate some polluting runoff from precipitation or snowmelt percolating through these wastes.

The waste pile should be removed. Most of these wastes can be dumped back into the mine openings using standard construction equipment. Excess wastes should be removed from the site and dispersed onto low lying areas with a mixture of natural soils and/or buried in excavated pits, covered over, and revegetated.

Upper Cottonwood "C"

The depth and instability of the large open adit are a significant safety hazard. The extensive fractures and the large masses of loose and falling rock are life-threatening to any persons or animals entering the adit. The massive sandstone caprock forming the roof of the adit should be drilled and blasted to collapse the site and fill the open adit area.

The large pile of mine wastes have blocked part of the natural drainage from the bench land above the site and also contribute some polluted runoff to Cottonwood Creek. These wastes should be removed and the former coulee restored.

There are an estimated 3,000 to 5,000 cubic yards of material in these waste piles which can be transported 200 feet uphill to backfill the benched area in front of the former mine site. Some of the surrounding native soil should be used to construct a 6 inch layer of cover soil over the wastes, and the resulting surface should be vegetated.

The seepage along the face of the hillside must be contained to prevent continued loss of topsoil and vegetation. A large drainage gallery should be installed along the hillside to intercept the seepage below the ground surface. The seepage should be contained in a conduit and discharged into the ditch containing the flow of mine effluent from the SCM-9 mine.

Anaconda Mine - Belt, Montana

The close proximity of the Anaconda Mine to the town of Belt and to many residences along its east side present a significant attractive nuisance and an impending safety threat. The adit is open for over 50 feet into a massive and failing sandstone bedrock roof and ribs. There are many loose rock slabs along the roof of the adit which appear to be on the verge of falling at the slightest disturbance. Some of these slabs are over 4 to 6 feet in diameter and weigh between 2 and 4 tons.

An estimated 6,000 to 8,000 cubic yards of waste rock, coal, and other associated debris from the former mine are located on the hillside below the adit. These wastes extend for over 200 yards along the east side of the County road serving the western edge of the town. Precipitation and run-off from the hill above and from the County road penetrate most of these wastes and eventually discharge into Belt Creek. Because of the thickness and nature of these wastes little or no vegetation has been established along this area.

The existing adit should be partially back filled with the wastes located below the County road. The large excavation in the hillside which leads into the adit should be back filled to restore the original contour of the hillside. A thin veneer of topsoil from the hillside surrounding the back filled area should be borrowed to provide a minimum of 6 inches of topsoil over the site.

All of the mine wastes located below the County road area can be reused to backfill thus leaving the former natural ground surface for reclamation. Plans are to recontour the

area to a stable and natural slope configuration to revegetate the site.

There is little that can be done to reduce or eliminate the significant AMD emanating from the mine which surfaces through the wastes below the County road. The AMD should be contained, collected, and piped to the existing channel east of the railroad tracks. Construction will require a collection system, piping, and outlet and will include boring of jacking a casing through the railroad right-of-way. Collection and conveying the AMD away from the waste piles reclamation area would allow reclamation of all of the impacted area between the County road and the railroad right-of-way, thus resulting in a more complete reclamation effort.

RECLAMATION COST ESTIMATES

The preliminary engineering analysis for the Phase I report, as set forth in the scope of work contained in the proposal includes generalized cost estimates for construction of the recommended alternatives. At this time aerial photos and topographic maps for the sites in this study are not available, thus earth work quantities, slack and waste pile boundaries and volumes, discharge and runoff facilities, channel and structures designs, and areas for soil amendments and revegetation were estimated.

Cost estimates for the proposed reclamation projects at each site are listed below. These estimates are based on field observations, general knowledge of the methodologies to be implemented, and information from previous and/or similar studies. Preliminary cost estimates were compiled using methodologies or equipment compatible with our recommendations for reclamation at the particular site. Sources of data for estimating purposes included discussions with contractors engaged in similar work, costs from past reclamation projects, experience of Delta Engineering personnel, and published cost estimating guides.

The estimates provided in Phase I are tentative and are provided for review and planning at this stage. Detailed cost estimates will be derived on a site specific basis from the reclamation alternative and methods selected by the DSL and will be provided with the Phase II engineering.

AMR Site	Estimated Range of Reclamation Costs
Centerville "C"	$ 40,000.00 - $ 50,000.00
Stockett West Ridge	$140,000.00 - $160,000.00
Upper Cottonwood "A"	$ 16,000.00 - $ 20,000.00
Upper Cottonwood "B"	$ 40,000.00 - $ 50,000.00
Upper Cottonwood "C"	$ 60,000.00 - $75,000.00
Belt - Anaconda Mine	$ 80,000.00 - $100,000.00

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